THE ASTER DEPLOYMENT

AT THE

COTTON SITE

DURING THE

CALIFORNIA OZONE DEPOSITIONAL EXPERIMENT, 1991
CODE '91

OF THE

SAN JOAQUIN VALLEY AIR QUALITY STUDY

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Boulder, Colorado, 80307, U.S.A.

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Rocky Mountain Forest and Range Experimental Station
United States Forest Service

1993 February

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Brief description of the Project

Dry deposition is an important sink for pollutants and consequently it plays an important role in the formulation of the lower boundary condition in photochemical and pollution transport models. Because dry deposition is important for modeling purposes, the California Air Resources Board sponsored a large field program in July and August of 1991 to study the dry deposition of ozone in the San Joaquin Valley. This field experiment,called the California Ozone Deposition Experiment (CODE) is part of the larger San Joaquin Valley Air Quality Study. CODE was designed to provide information on the nature of the physical and biological processes governing the dry deposition of ozone in the San Joaquin Valley and for developing and evaluating air quality models for that region.

SYNOPSIS OF FIELD PHASE

The San Joaquin Valley Air Quality Study (SJVAQS) ASTER deployment was sponsored by the California Air Resources Board of the state of California to quantify the ozone deposition flux to crop vegetation and served to produce imput data for the air quality models used for regulatory purposes.

Bill Massman and Larry Marht were the principal investigators and Jim Pederson was the contact manager for the CARB. Tony Delany was the ASTER scientist and Steve Semmer the ASTER engineer. Tom Horst, Steve Oncley and Charlie Martin were involved in the ASTER research. In addition to the ASTER cotton field investigation two other ground based surface flux facilities were deployed; the Environment Canada facility (Gerry den Hartog) in a raisin grape vinyard, and the University of California at Davis (Roger Shaw) in a dry grass field. The Environment Canada instrumented Twin Otter aircraft (Ian McPherson) overflew all sites. Sonoma Tech, a consulting firm, was responsible for site preparation.

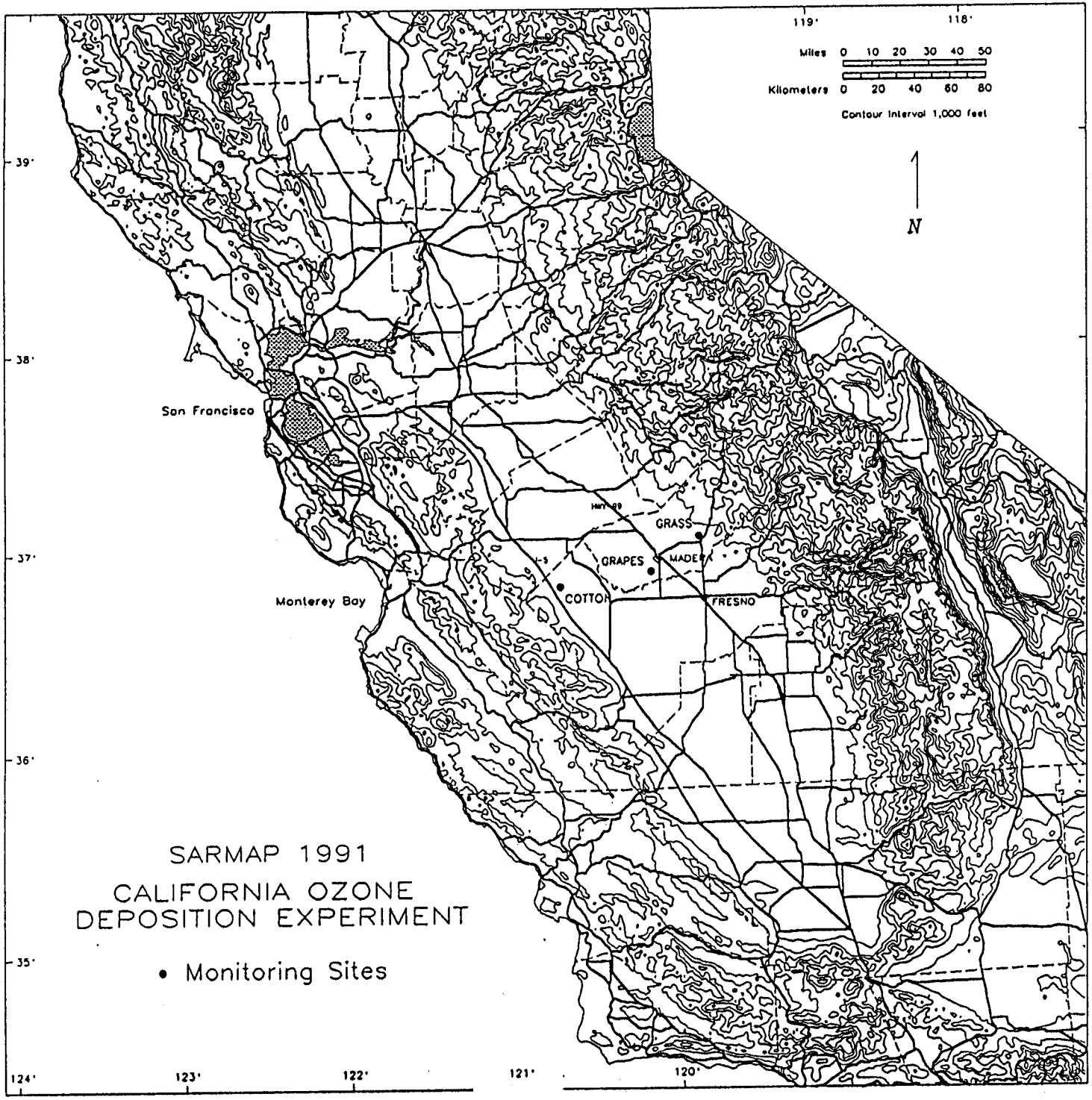
Prior to the field phase a planning meeting was held at the office of the CARB in Sacramento. Tony Delany attended and made preliminary arrangements as to site requirements. The general location of the research site was determined by Ian McPherson and Paul Hanson of Sonoma Tech. Tom Horst and Steve Semmer made a site visit to check the micrometeorological validity of the site and the logistics for the deployment.

The truck containing the field-ware and the single ASTER seatainer arrived at the site 25 June 1991 and the walk-ways, towers, power and data cabling was laid out. Some postponement was involved due to a delay in the installation of the power drop. The sensor installation was completed by 7 July 1991 and the system was operational on 11 July 1991. A rental trailer required for the PG and E monitors, the suppies for the pilot balloon system operated by Fresno State College, and the contents of the ASTER second seatainer was positioned south of the ASTER seatainer. The NOAA WPL mini-sodar was south of the PG and E trailer. Operations were continuous from 11 July to 7 August (JD 192 - JD 219) 1991. Tear-down and repacking of the trailers occupied a four day period.

The ASTER site was located 80 km west of Fresno in the central valley of California. Maps 1 and 2 show the location of the site relative to urban areas and the major highways. Maps 3 and 4 illustrate that the facilty was situated in an extremely open flat agricultural area of cotton, tomatoes, melons and beans with very few obstructions and with access roads and irrigation canals on the section or quarter section boundaries. A skyline survey indicates the scacity of nearby obstructions. The tower array was erected 150 m from the eastern edge of a cotton field. The site plan illustrates the relative

positioning of the five towers, the radiation array, the instrument shelters and the access walkways. Of particular note is the exhaust for the fast ozone sensor vacuum pump. Under the prevailing meteorological conditions the NOX laced exhaust was emitted down-wind of the ASTER array and sufficiently cross-wind from the PG and E that it was not sensed. However during quiescent nighttime conditions the exhaust spread across the site and represented a problem.

The site plan and the sensor configuration diagram show the arrangement of the meteorological, chemical, and radiation instruments. The soil temperature and heat flux sensors were located near the dark-horse, the 4m stand upon which the radiation sensors were mounted. The soil sensors were distributed such that both ridge and furrow were represented. Samples were taken each day from both ridge and furrow to measure the gravitational soil moisture.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• Monitoring Sites
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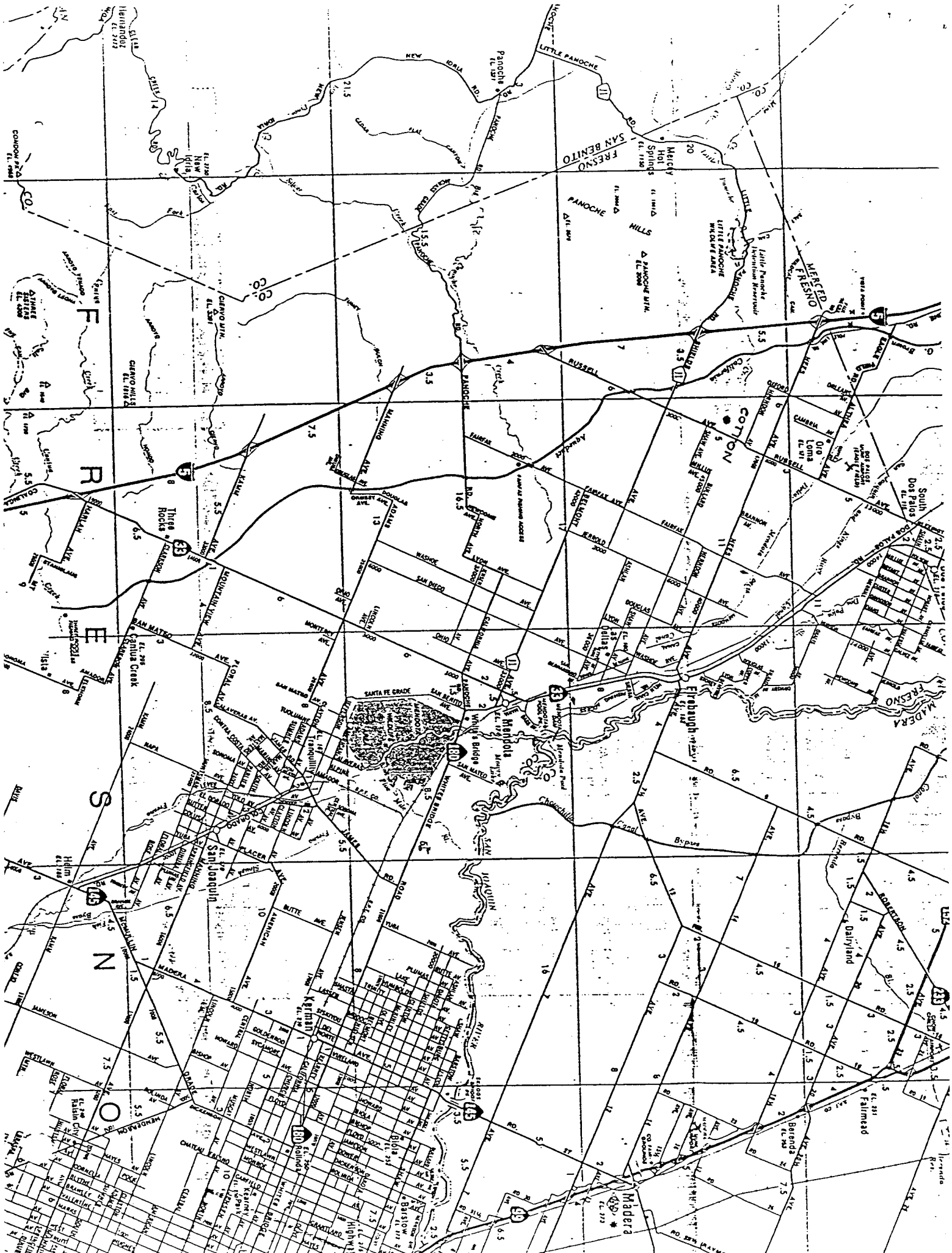
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Berenda
Dairyland
Colton
South Dos Palos
Oro Loma
Chowchilla
Bypass
Canal
Highway
Railroad
Fresno
Merced
San Benito
Panoche Hills
Little Panoche
Cervo Mtn.
Athens
Condon Mtn.
Panoche Mtn.
Little Panoche Reservoir
Little Panoche Wilderness Area
Alamedian Pond
Santa Fe Grade
Russell
Fairfax
Washoe
San Diego
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San Mateo
Tuolumne
Contra Costa
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Merced
San Benito
Monterey
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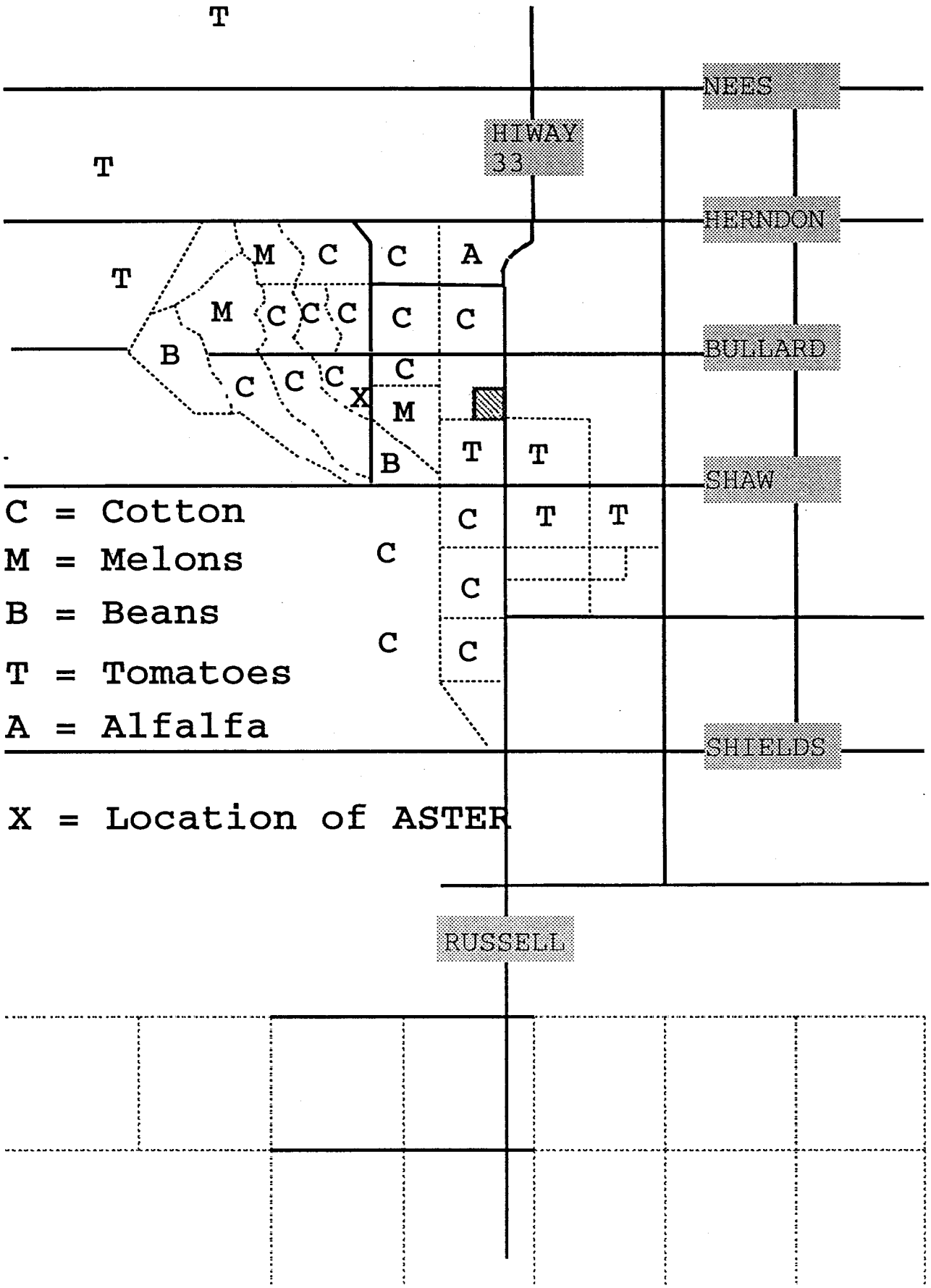
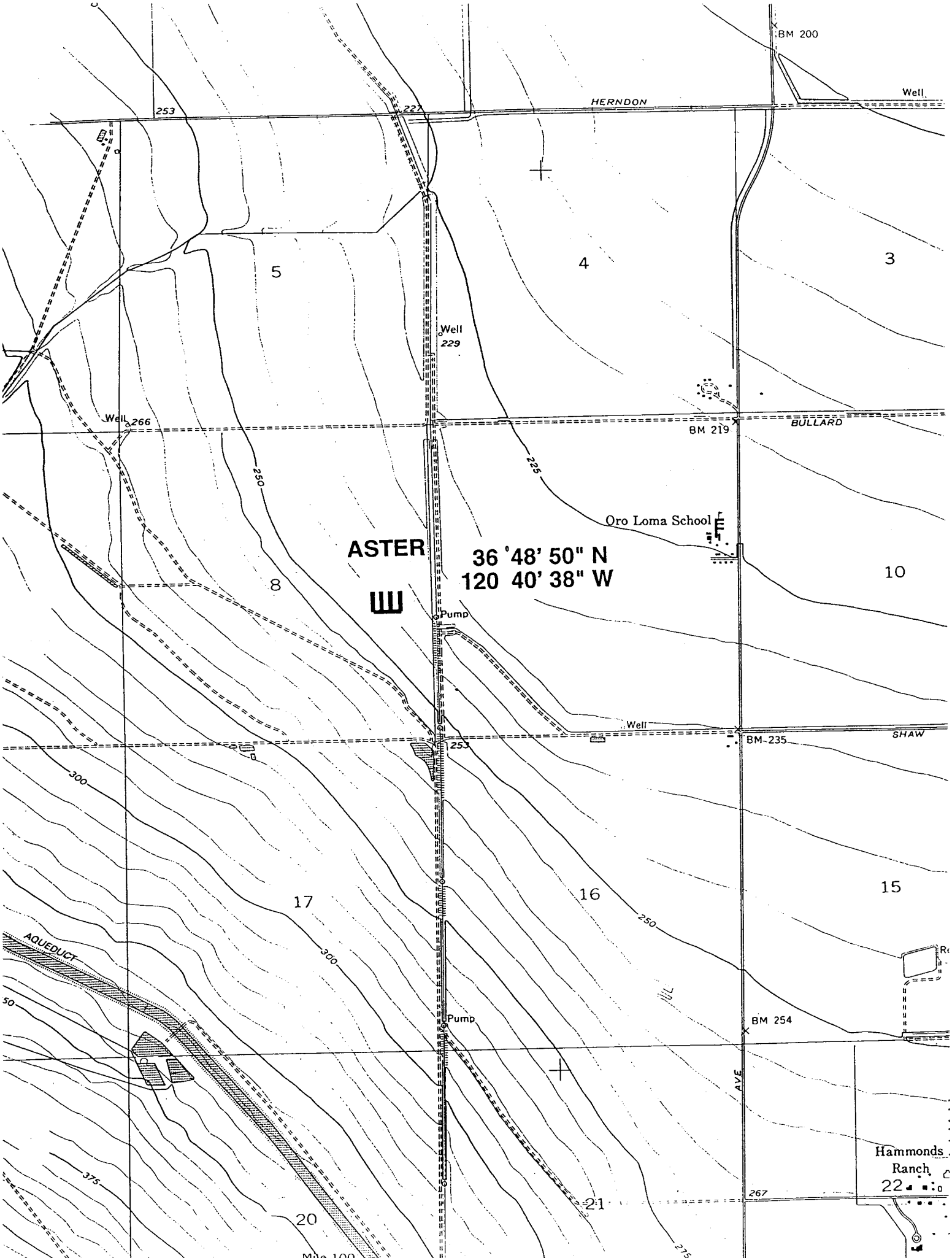
Ventura
Los Angeles
San Bernardino
Riverside
Orange
San Diego
Imperial

SJVAQS crop map

Information obtained from Bill Nicholas of Hammonds Ranch

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229
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BM 219
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225
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120 40' 38" W
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BM-235
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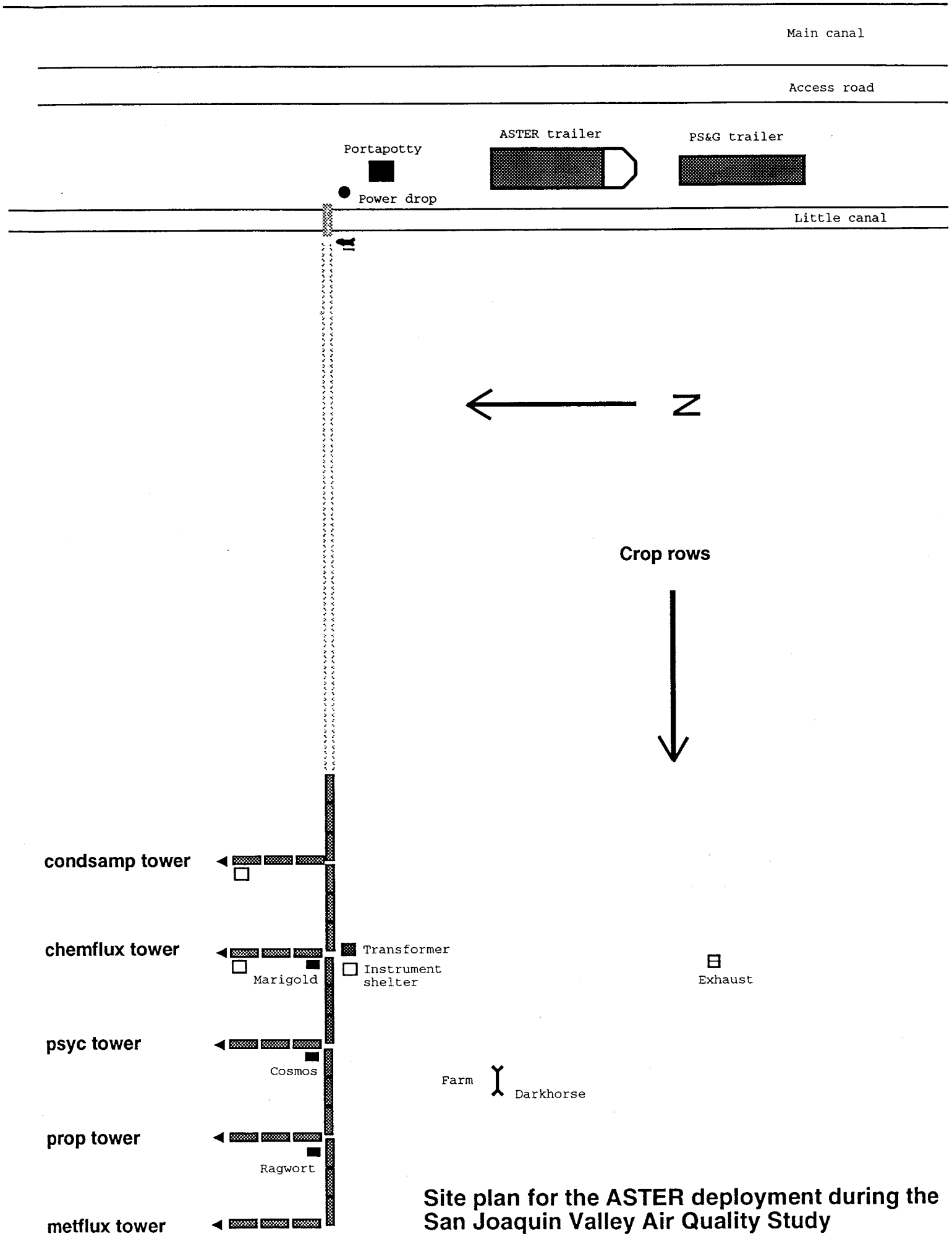
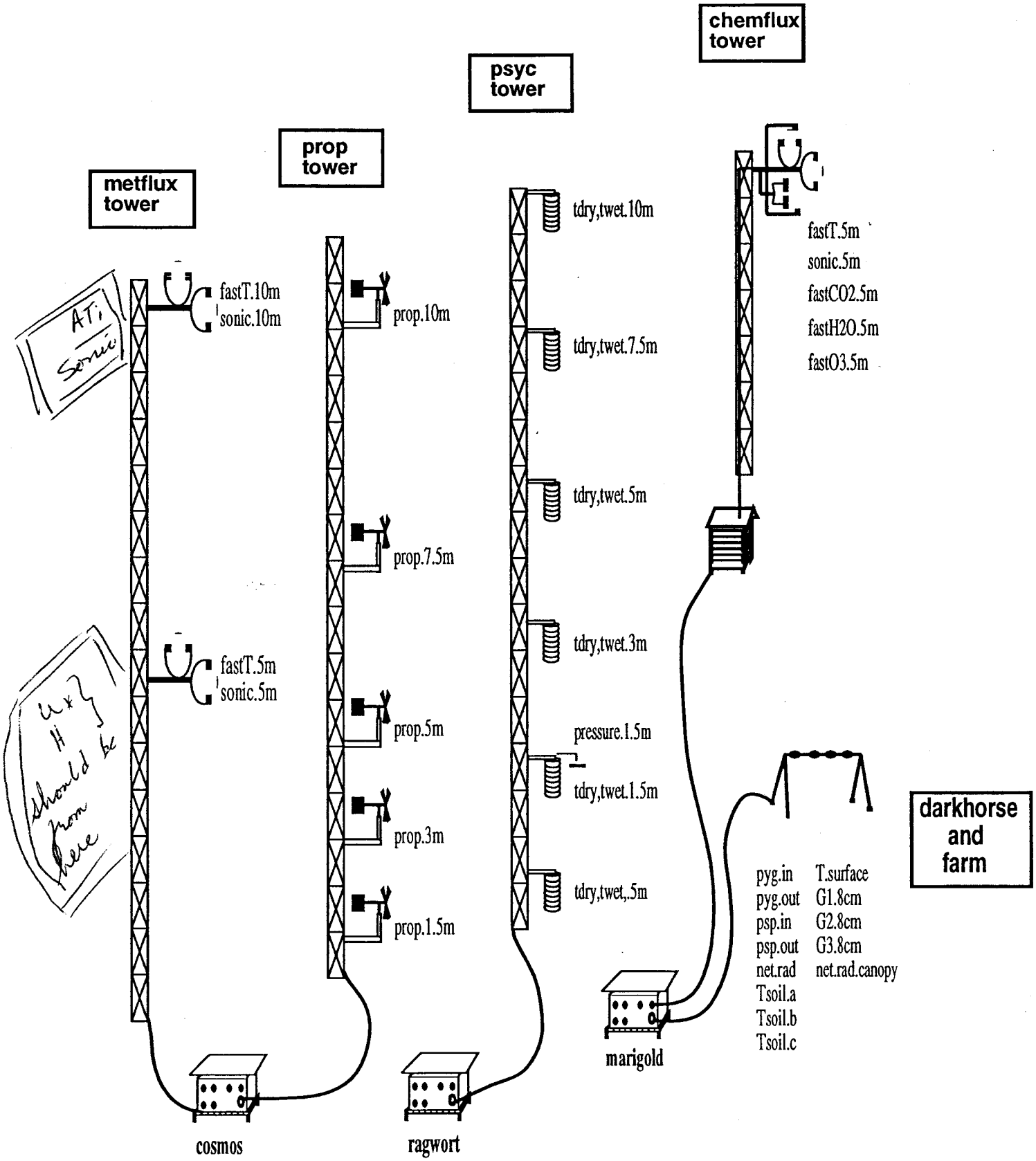
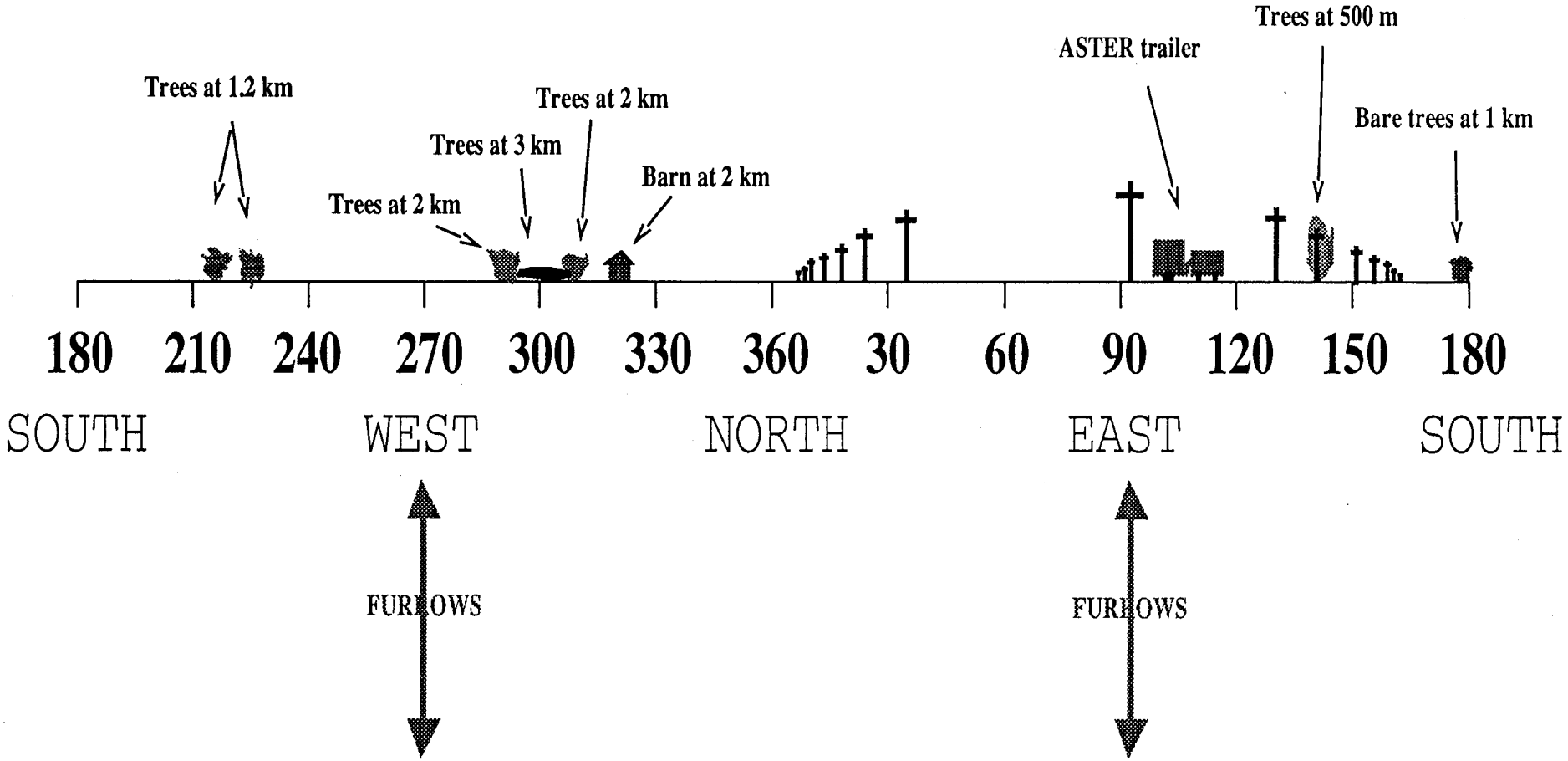


Site plan for the ASTER deployment during the San Joaquin Valley Air Quality Study



The sensor array and ADAM configuration for ASTER during the San Joaquin Valley Air Quality Study 1991

SJVAQS skyline survey



ASTER Sensors deployed during SJVAQS91

Sensor	Number	Make	Location	Height
3-Dimensional sonic anemometer	2	Univ of Wash	Metflux Twr	10, 5m
1-Dimensional sonic anemometer	1	Applied Technologies	Chemflux Twr	5m
Fast-response temperature sensors	3	Atmos. Instrumentation Res.	Metflux Twr Chemflux Twr	10, 5m 5m
Wind speed and direction	5	NCAR propvane	Prop Twr	1.5, 3.5, 7.5, 10m
Dry and wet bulb temperature	6	NCAR psychrometer	Psyc Twr	.5, 1.5, 3, 5, 7.5, 10m
Pressure Sensor	3	NCAR barometer	Psyc Twr	1.5m
Pyranometers	2	Eppley psp	Darkhorse	4m up and down
Pyrgeometers	2	Eppley pyg	Darkhorse	4m up and down
Net radiometer	1	Micromet Systems Q-3	Darkhorse	4m
Surface infrared radiometer	1	Everest Interscience	Darkhorse	4m
Photosynthetically active rad	1	LI-COR LI-190SA	Darkhorse	4m
Soil temperature	2	NCAR serial device	Farm	8cm deep
Soil temperature	12	NCAR multiplexed device	Farm	1, 3, 5, 7cm deep
Soil heat flux	3	Micromet systems	Farm	8cm deep
Fast-response humidity	1	Campbell Scientific Kr hygrometer	Chemflux Twr	5m
Fast CO2 and H2O sensor	1	NCAR/KMNI ir device	Chemflux Twr	5m
Fast O3 sensor	1	NASA Ames	Chemflux Twr	5m

CODE Cotton site, parameters available as 30 minute averages.

The time to be used is Pacific Daylight Time. (PDT = GMT - 7)
When data is absent or suspect -99 is used.

Item	Units	Name
1 TIME	YY JJJ HH MM	The time reported in the form shown
2 ITBRK	0 or 1	0 if 30 minute data absent, 1 if present
3 SWO	W m-2	Short Wave Out
4 SWI	W m-2	Short Wave In (Solar radiation)
5 LWO	W m-2	Long Wave Out corrected for dome and case temperatures
6 LWI	W m-2	Long Wave In corrected for dome and case temperatures
7 Rn	W m-2	Net radiation
8 PAR	umole m-2 s-1	Photosynthetically Active Radiation
9 E	mg m-2 s-1	Water vapor flux Krypton hygrometer and sonic on chemflux tower at 5meters
10 LE	W m-2	Latent ht flux
11 Hs	deg ms-1	Sensible ht flux Fast temp sensor and sonic on metflux tower at 5meters
12 H	W m-2	Sensible ht flux
13 P	kPa	Pressure
14 ustar	ms-1	Friction velocity Sonic on metflux tower at 5 meters
15 zoL		Stability parameter at 5 meters
16 Tsurf	degC	Infrared surface temp of leaf and soil (seen from the 4 m dark-horse)
17 Tsoil	degC	Infrared soil surface THIS DATA IS NOT AVAILABLE
		The following are soil temps for furrow and ridge using serial device
18 Tsoil8r	degC	Soil temp 8cm ridge
19 Tsoil8Nf	degC	Soil temp 8cm furrow
20 Tsoil8	degC	Soil temp 8cm mean = mean(Tsoil8r, Tsoil8f)

The following are soil temps for N furrow, ridge, and S furrow at 1, 3, 5, 7 cm

21	Tsoil1Nf	degC	
22	Tsoil3Nf	degC	
23	Tsoil5Nf	degC	
24	Tsoil7Nf	degC	
25	TsoilNf	degC	The weighted mean of the 1, 3, 5, 7, cm Nf temperatures
26	Tsoil1r	degC	
27	Tsoil3r	degC	
28	Tsoil5r	degC	
29	Tsoil7r	degC	
30	Tsoilr	degC	The weighted mean of the 1, 3, 5, 7, cm r temperatures
31	Tsoil1Sf	degC	
32	Tsoil3Sf	degC	
33	Tsoil5Sf	degC	
34	Tsoil7Sf	degC	
35	TsoilSf	degC	The weighted mean of the 1, 3, 5, 7, cm Sf temperatures
36	G8Nf	W m-2	Soil ht flux 8cm N furrow
37	G8r	W m-2	Soil ht flux 8cm ridge
38	G8Sf	W m-2	Soil ht flux 8cm S furrow
39	G8	W m-2	Soil ht flux 8cm mean = mean (G8Nf, G8r, G8Sf)
40	GNf	W m-2	Soil ht flux surface N furrow
41	Gr	W m-2	Soil ht flux surface ridge
42	GSf	W m-2	Soil ht flux surface S furrow
43	G	W m-2	Soil ht flux surface mean = mean (GNf, Gr, GSf)
44	Ta.5	degC	Atmospheric temp at 0.5m
45	Ta1.5	degC	Atmospheric temp at 1.5m
46	Ta3	degC	Atmospheric temp at 3.0m
47	Ta5	degC	Atmospheric temp at 5.0m
48	Ta7.5	degC	Atmospheric temp at 7.5m
49	Ta10	degC	Atmospheric temp at 10.m

50 ea.5	kPa	Water vap. pres. at 0.5m
51 ea1.5	kPa	Water vap. pres. at 1.5m
52 ea3	kPa	Water vap. pres. at 3.0m
53 ea5	kPa	Water vap. pres. at 5.0m
54 ea7.5	kPa	Water vap. pres. at 7.5m
55 ea10	kPa	Water vap. pres. at 10m
56 q.5	g kg-1	Specific humidity at .5m
57 q1.5	g kg-1	Specific humidity at 1.5m
58 q3	g kg-1	Specific humidity at 3m
59 q5	g kg-1	Specific humidity at 5m
60 q7.5	g kg-1	Specific humidity at 7.5m
61 q10	g kg-1	Specific humidity at 10m
62 WD	degrees	Wind direction at 5 meters
63 Ua1.5	m s-1	Wind speed at 1.5 meters
64 Ua3	m s-1	Wind speed at 3.0 meters
65 Ua5	m s-1	Wind speed at 5.0 meters
66 Ua7.5	m s-1	Wind speed at 7.5 meters
67 Ua10	m s-1	Wind speed at 10. meters
68 SIGMAi	degrees	Wind direction variability at 5m
69 CO2M	mg m-3	Carbon dioxide concentration
70 CO2V	ppmv	Carbon dioxide mixing ratio
71 FCO2M	mg m-2 s-1	CO2 mass flux
72 FCO2E	W m-2	CO2 equivalent energy flux
73 O3V	ppbv	Ozone mixing ratio
74 O3M	ug m-3	Ozone concentration
75 FO3V	ppbv ms-1	Ozone flux
76 FO3M	ug m-2 s-1	Ozone mass flux
77 O3CAL	ppbv volt-1	Ozone calibration

This data set is in a space delineated ASCII matrix of 77 columns and 1344 rows.
This corresponds to the 77 parameters presented above and the 1344 30 minute periods.
The data is presented at a time corresponding to the end of the 30 minute period.
When the data is absent or suspect -99 is used.
The first 30 minute period commenced at 1700 10 July 1991 Pacific Daylight Time.
This corresponds to JD 192, 00:00

GRAPHICAL OUTPUT FOR SJVAQS REPORT

Local time and date along the bottom axis and JD and gmt along the top.

Each day starts at midnight local time.

Use multiple scaling for the different parameters.

DAILY OUTPUT OF SELECTED PARAMETERS

Five panels per page, one page per day and constant scaling throughout series

1. Temperature degrees C [10,40] **Ta5**;

   Pressure kPa [100,101.5] **P**;

   and Specific humidity gkg-1 [0,20] **q5**.

2. Wind speed ms-1 [0,10] **Ua5**;

   and Wind direction degrees [0,360] **WD**.

3. Net radiation Wm-2 [-100,700] **Rn**;

   Sensible heat flux Wm-2 [-100,700] **H**;

   Latent heat flux Wm-2 [-100,700] **LE**;

   and Surface heat flux Wm-2 [-100,700] **G**.

4. Stability [-2,2] **zoL**;

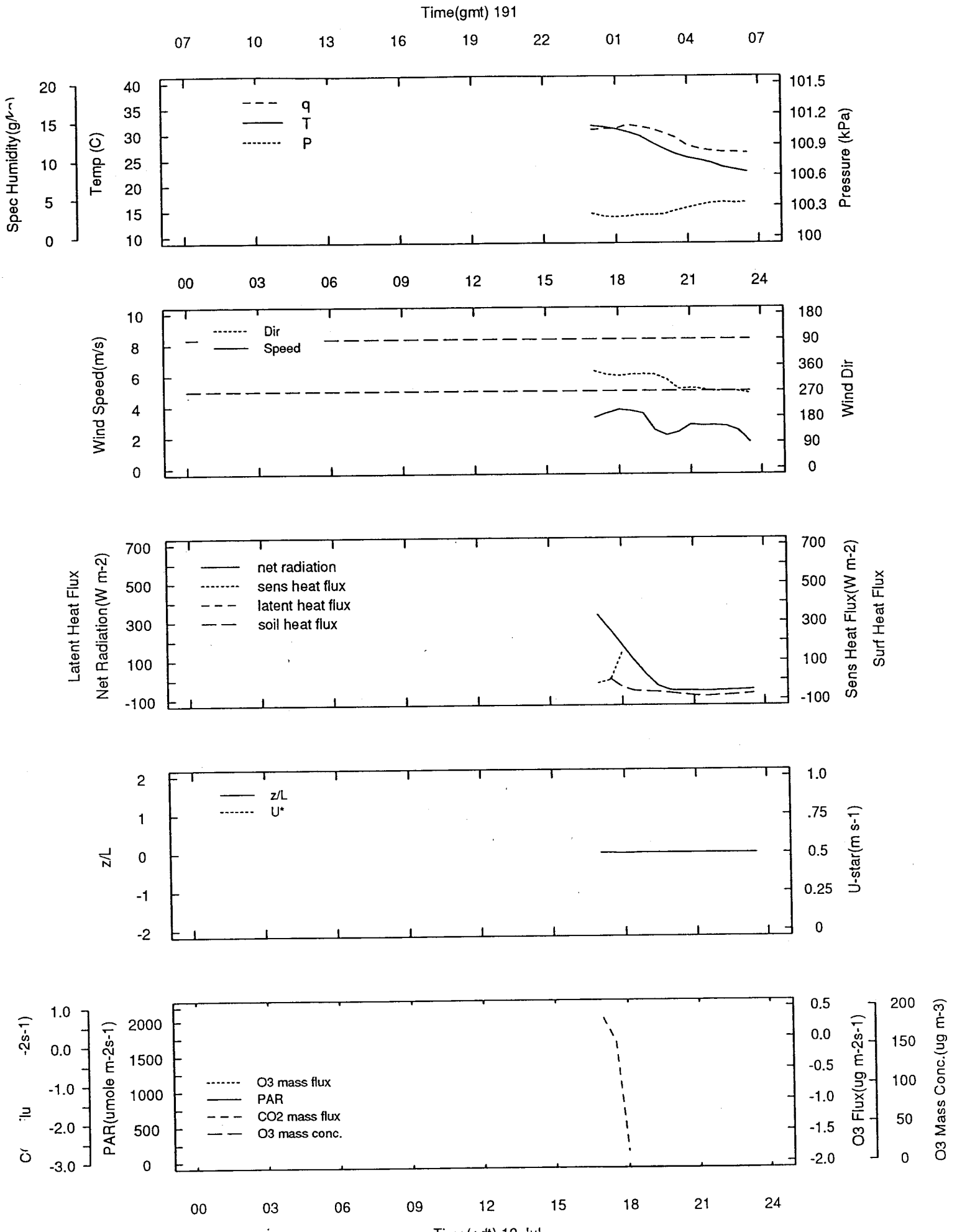
   and Stress m s-1 [0,1] **ustar**.

5. Photosynthetically active radiation umole m-2 s-1 [0,2200] **PAR**;

   Ozone mass depositional flux ug m-2 s-1 [-2.0,0.5] **FO3M**;

   Carbon dioxide mass depositional flux mg m-2 s-1 [-3.0,1.0]**FCO2M**;

   Ozone concentration ug m-3 [0.0,200.0]**O3M**.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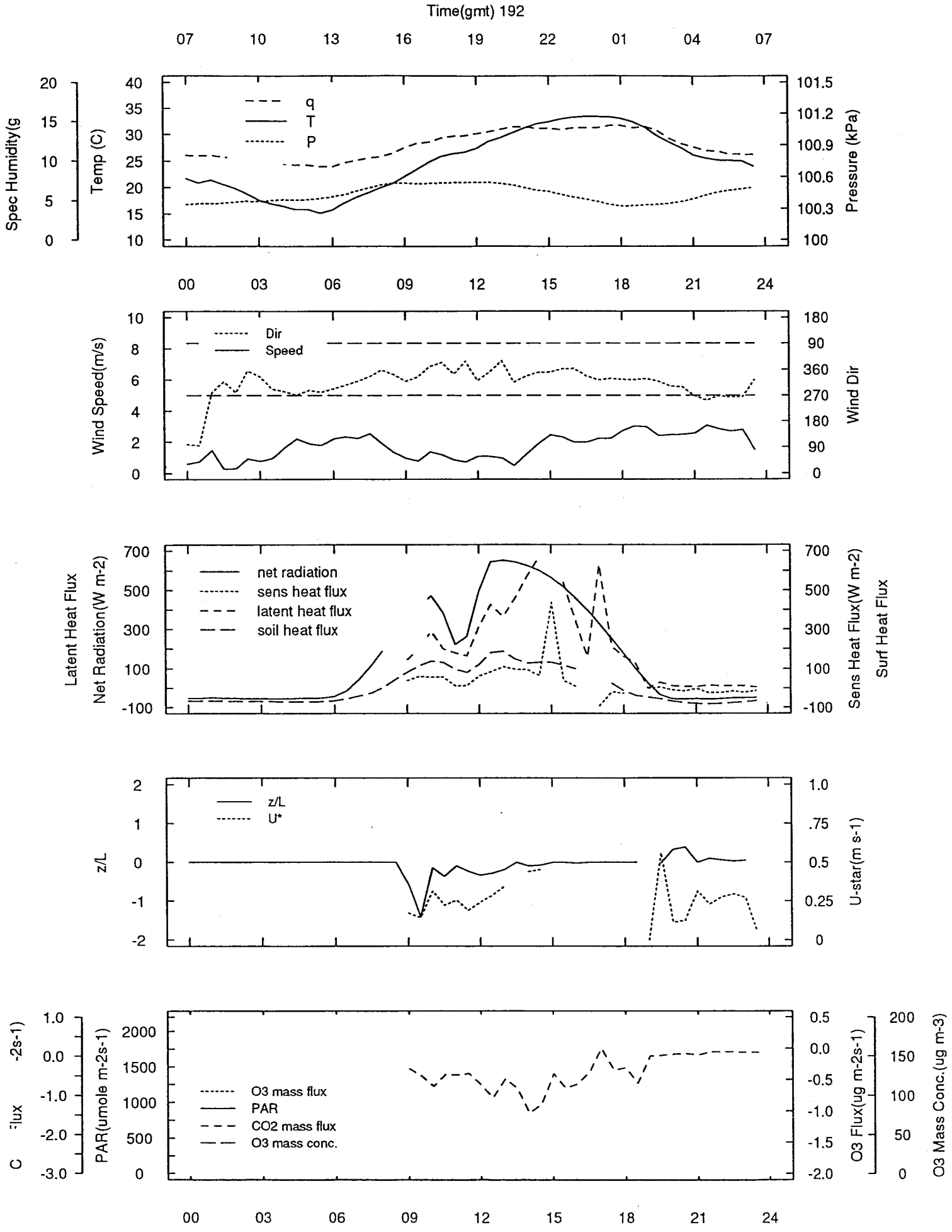
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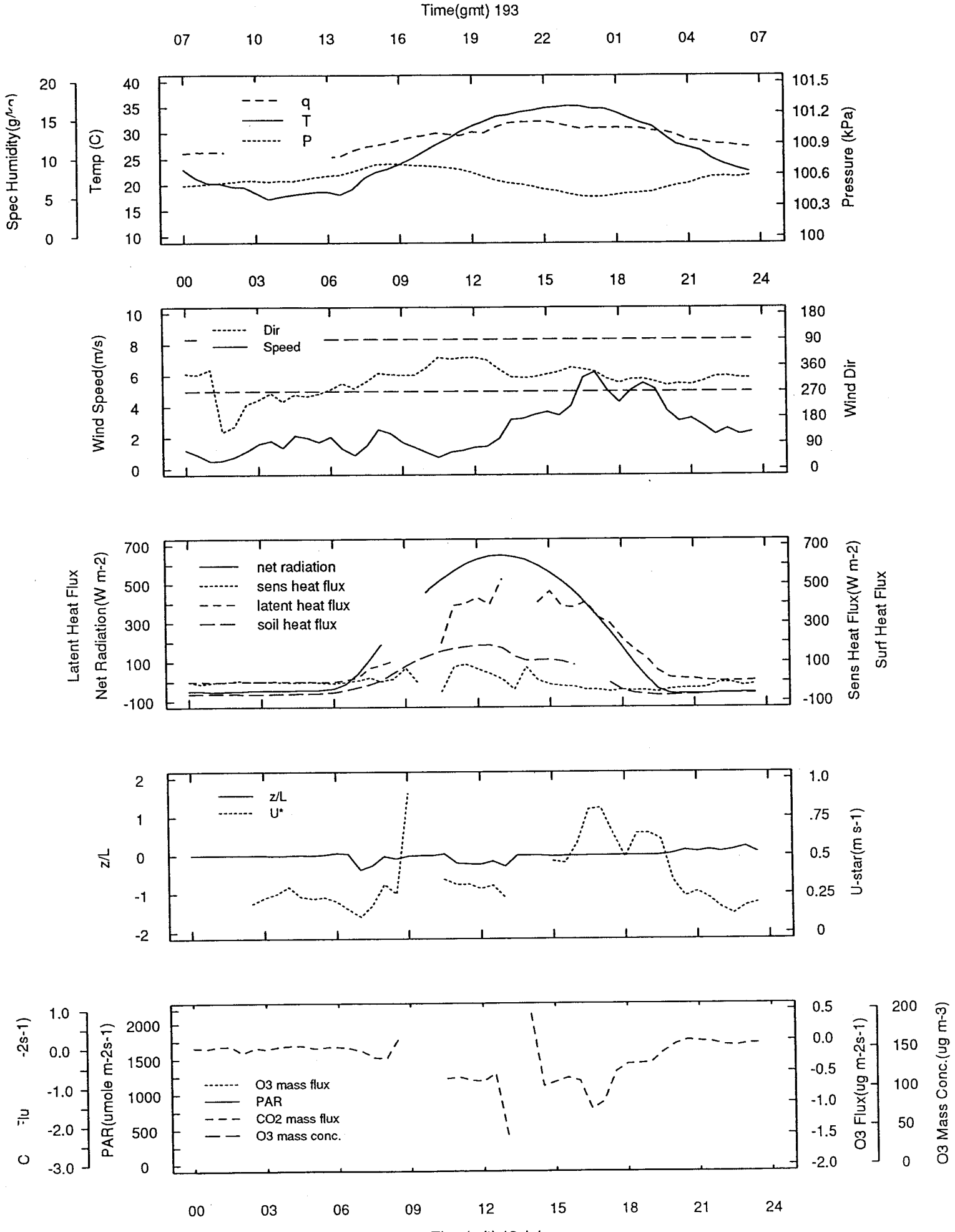
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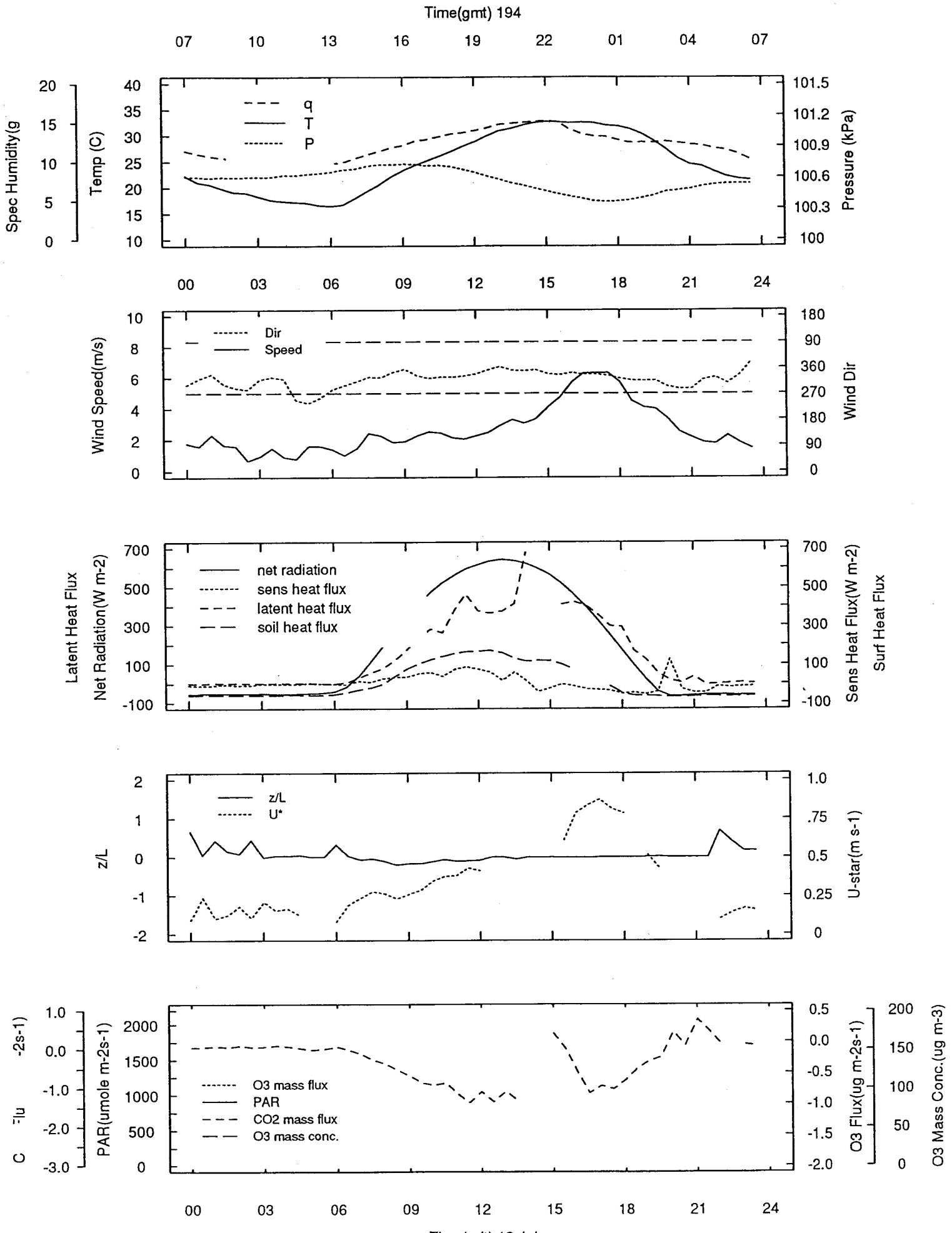
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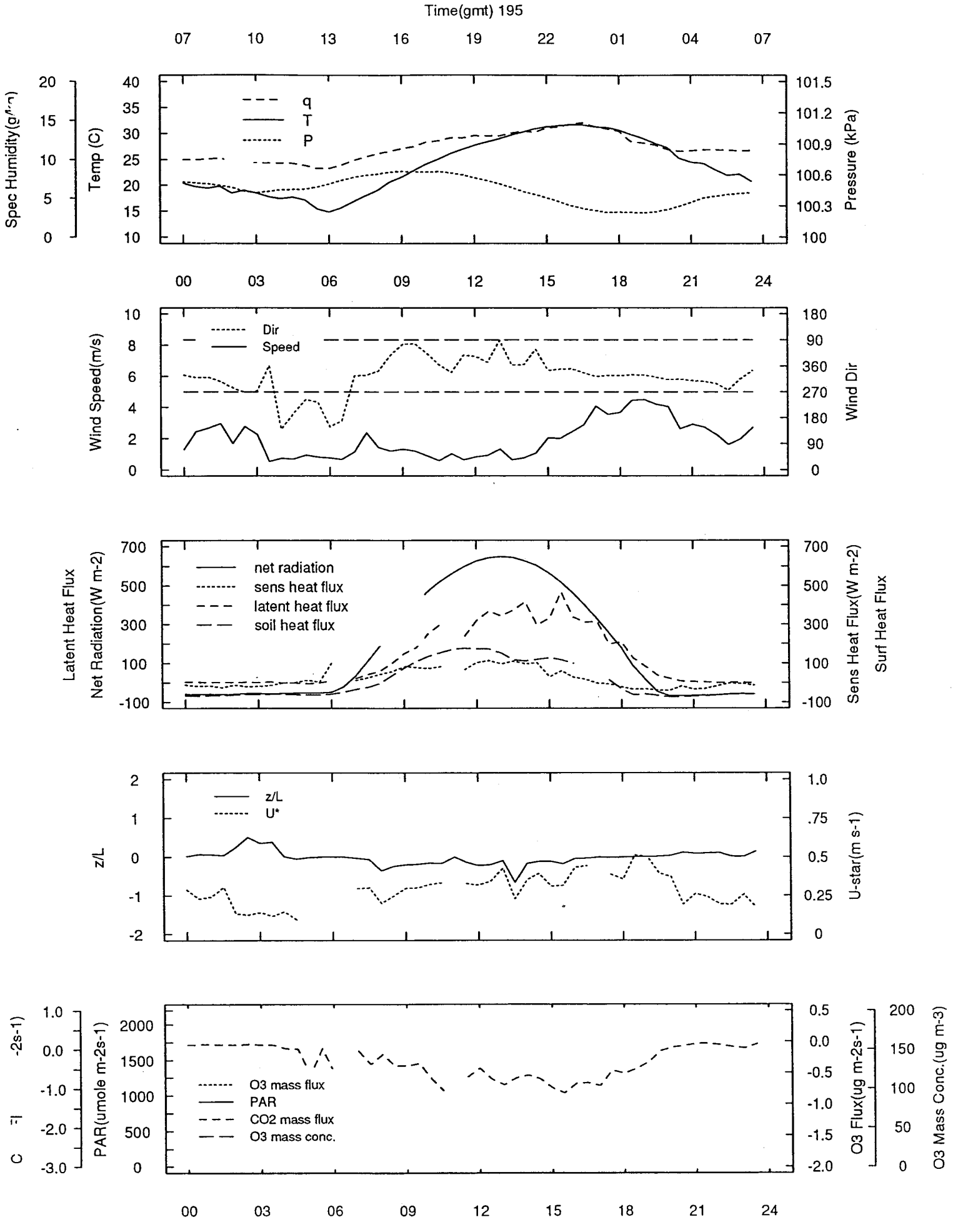
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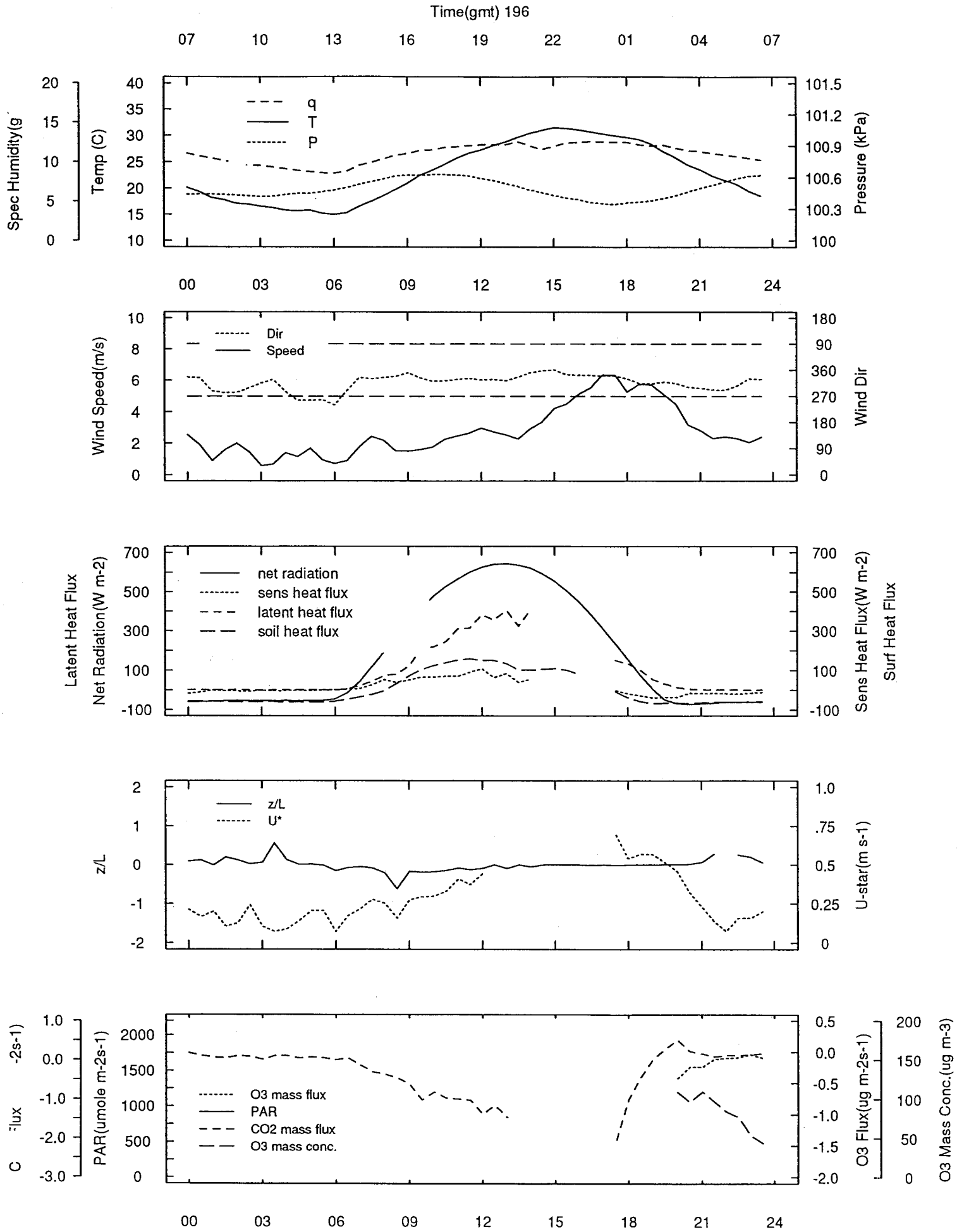
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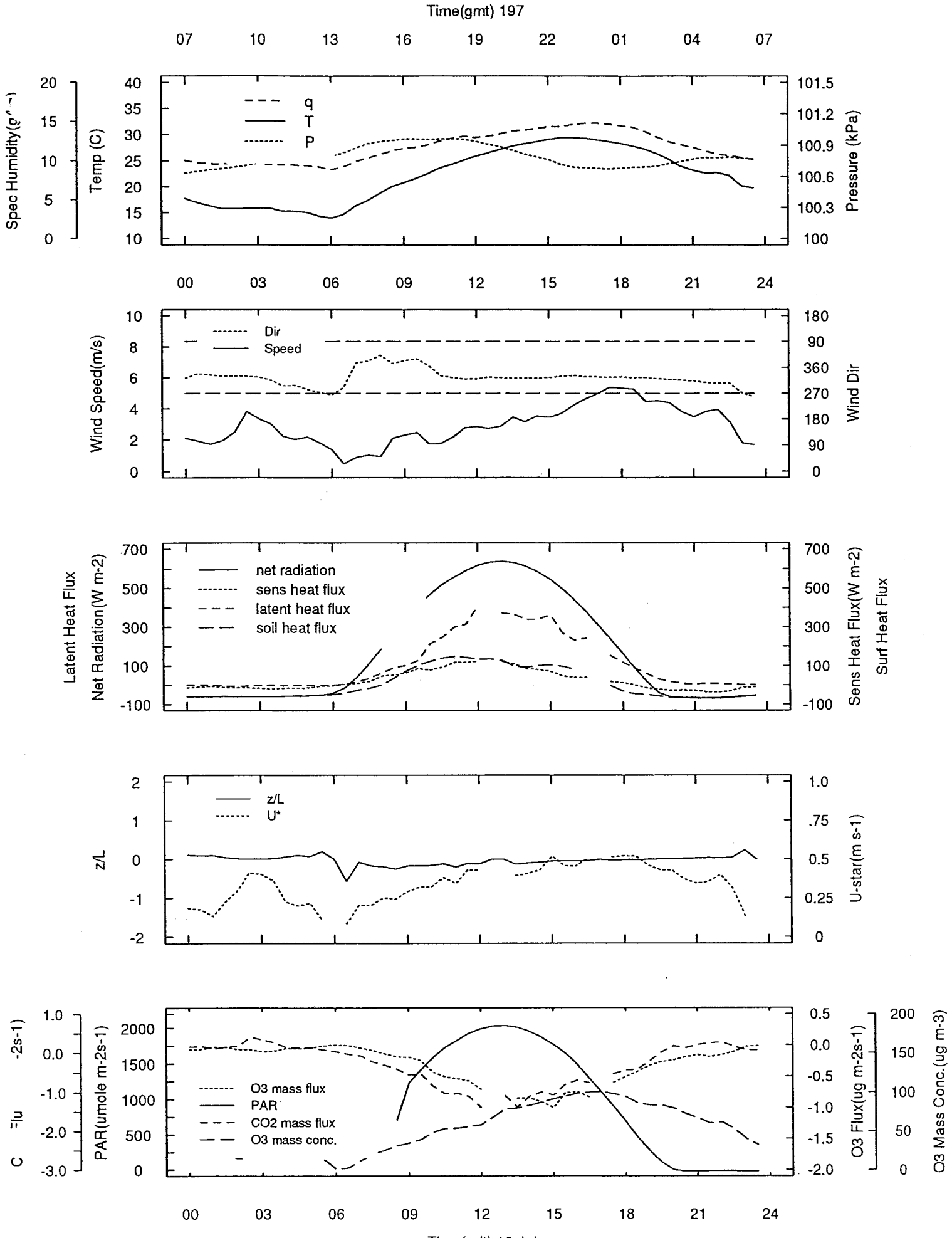
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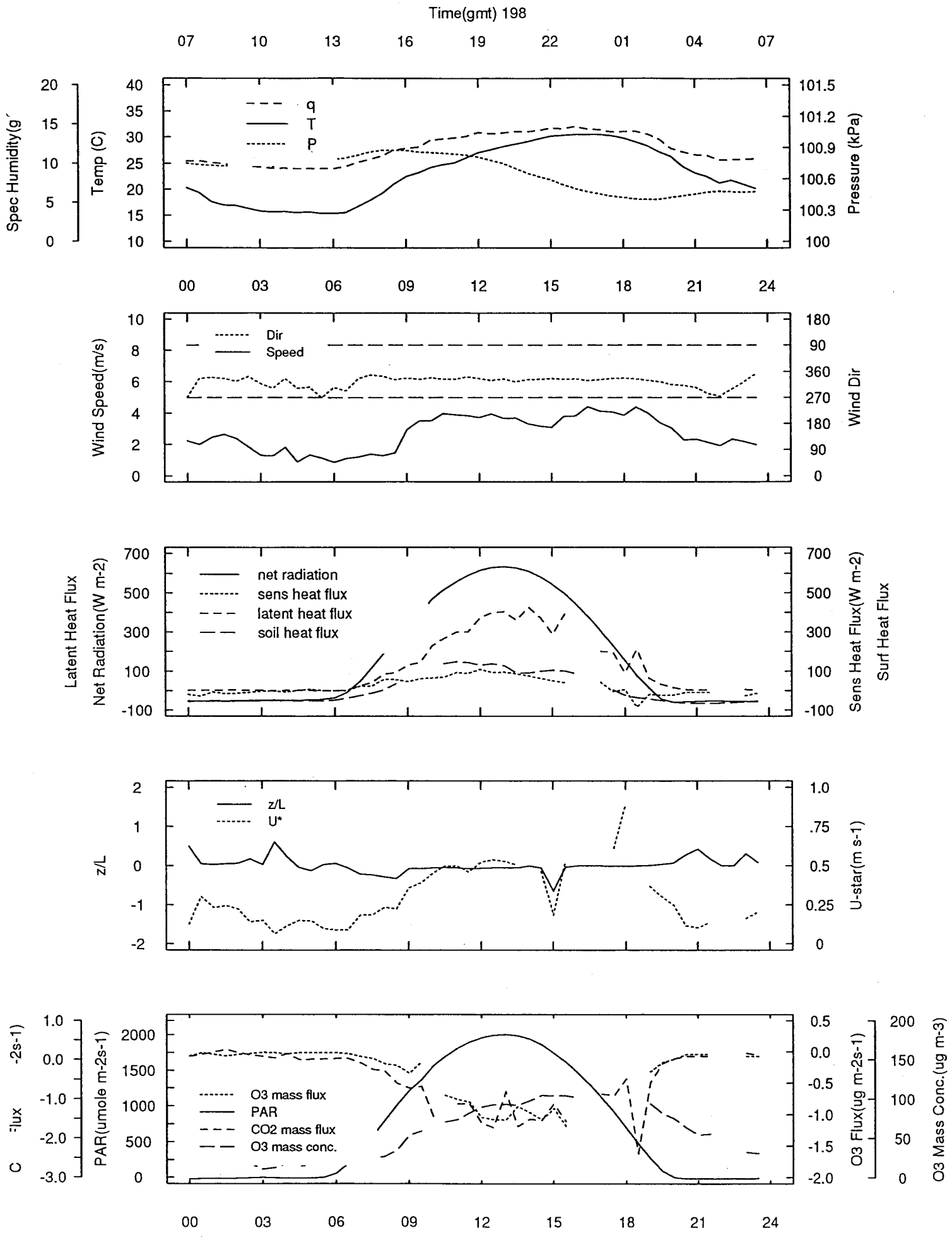
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.


Time(gmt) 198
07
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16
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07
Spec Humidity(g
Temp (C)
q
T
P
Pressure (kPa)
00
03
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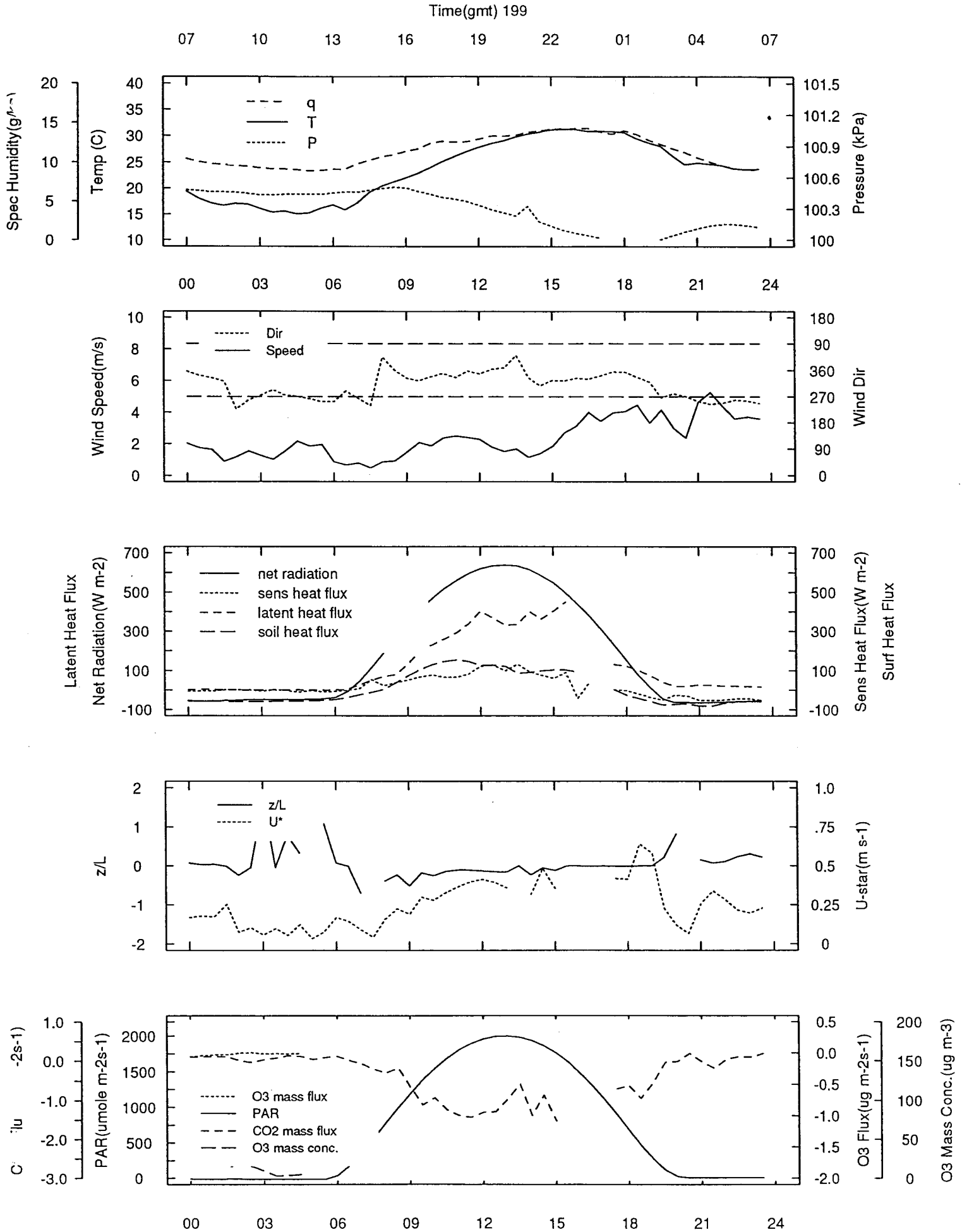
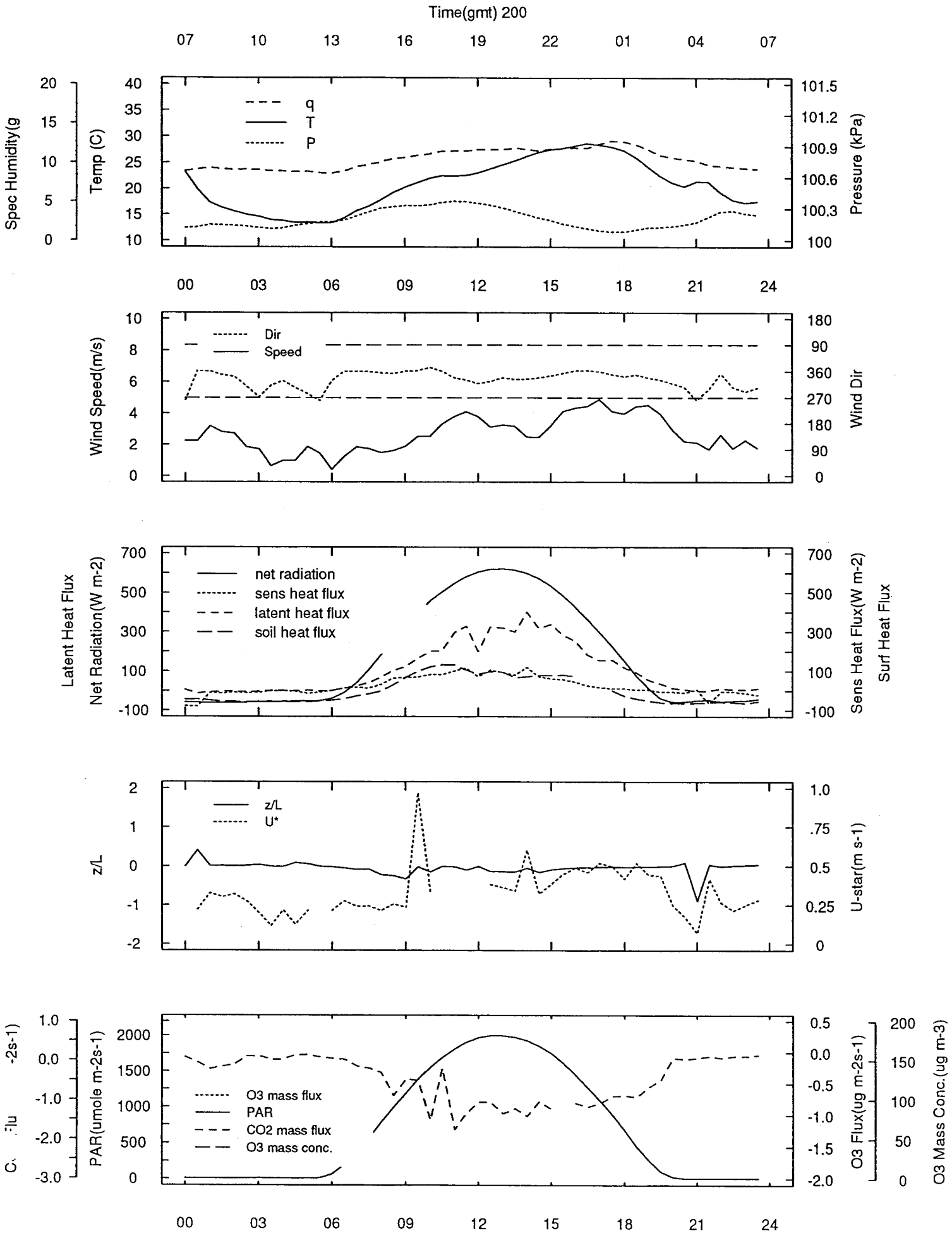
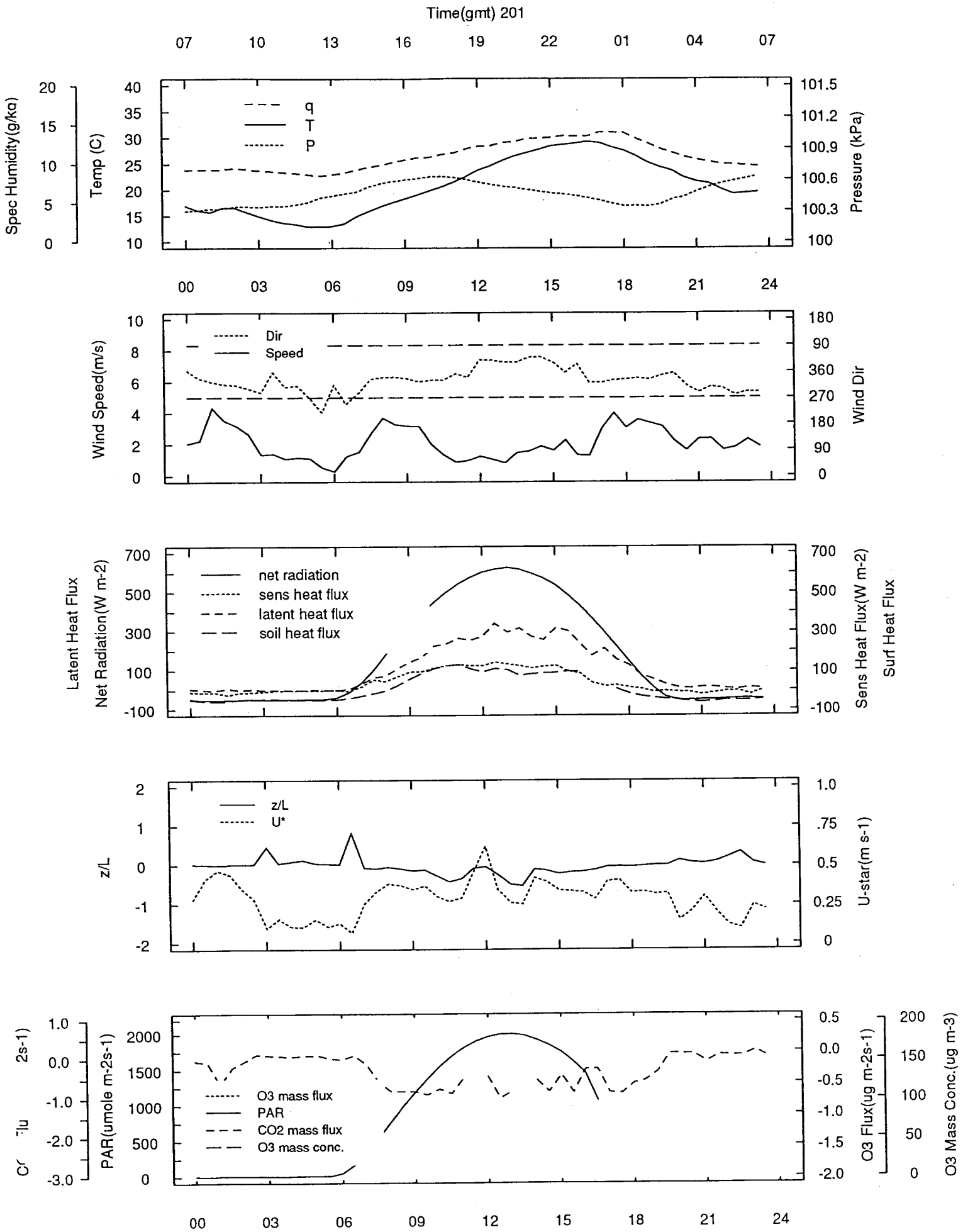
15
18
21
24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
C flux -2s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)


Time(gmt) 199
07 10 13 16 19 22 01 04 07
Spec Humidity(g/
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24


Time(gmt) 200
07 10 13 16 19 22 01 04 07
Spec Humidity(g
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24


Time(gmt) 201
07 10 13 16 19 22 01 04 07
Spec Humidity(g/kg)
Temp (C)
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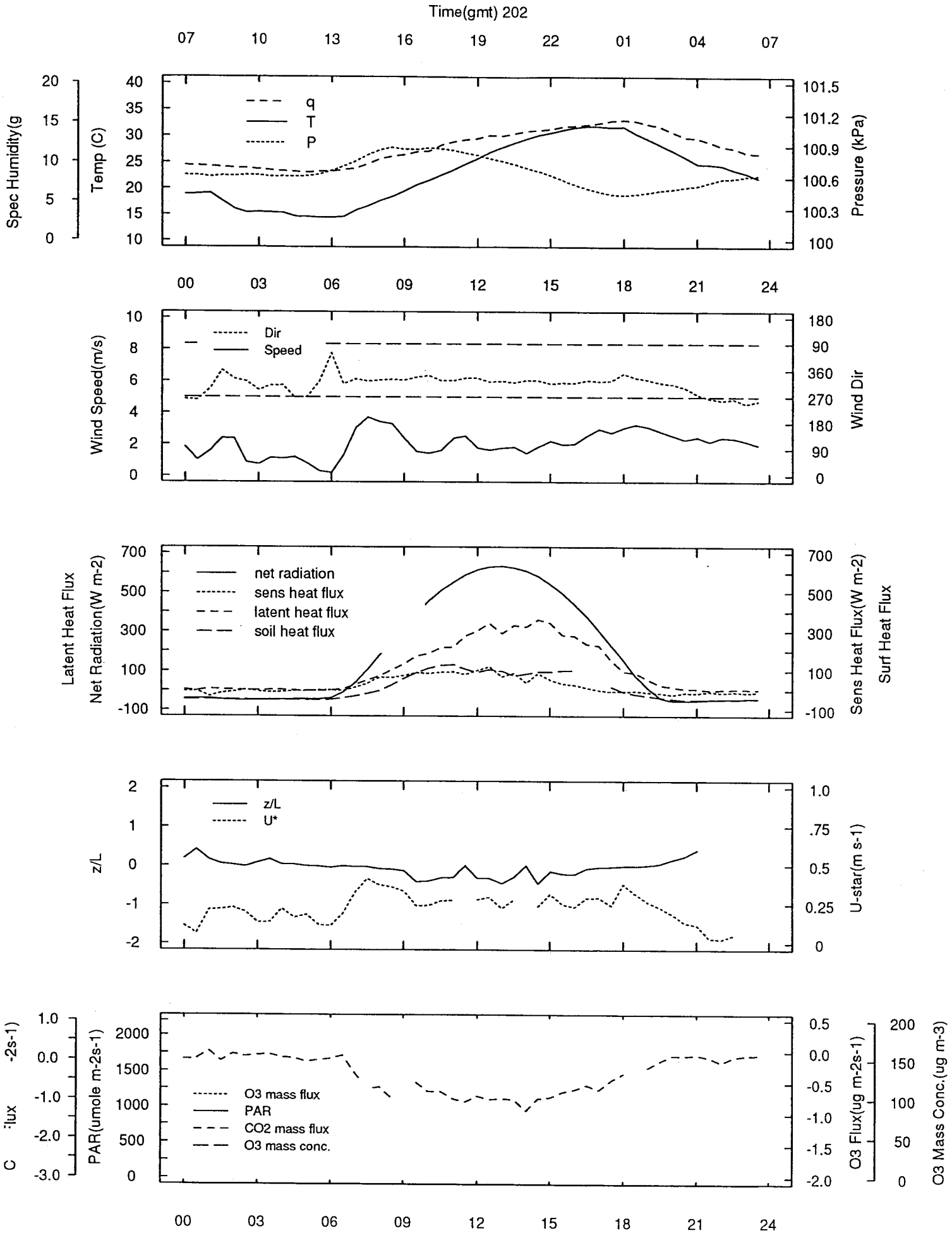
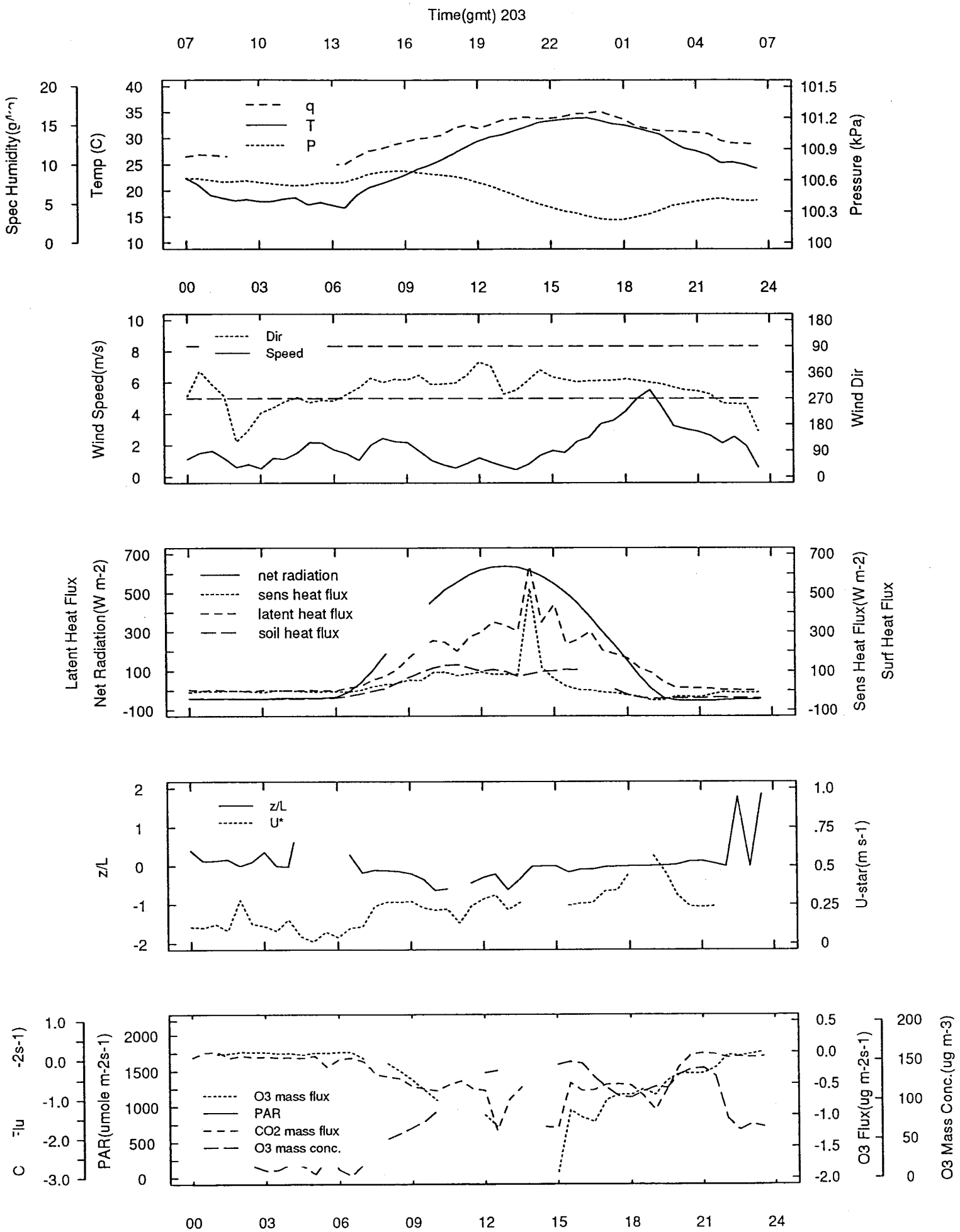
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24


Time(gmt) 202
07 10 13 16 19 22 01 04 07
Spec Humidity(g
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24


Time(gmt) 203
07 10 13 16 19 22 01 04 07
Spec Humidity(g/kg)
Temp (C)
Pressure (kPa)
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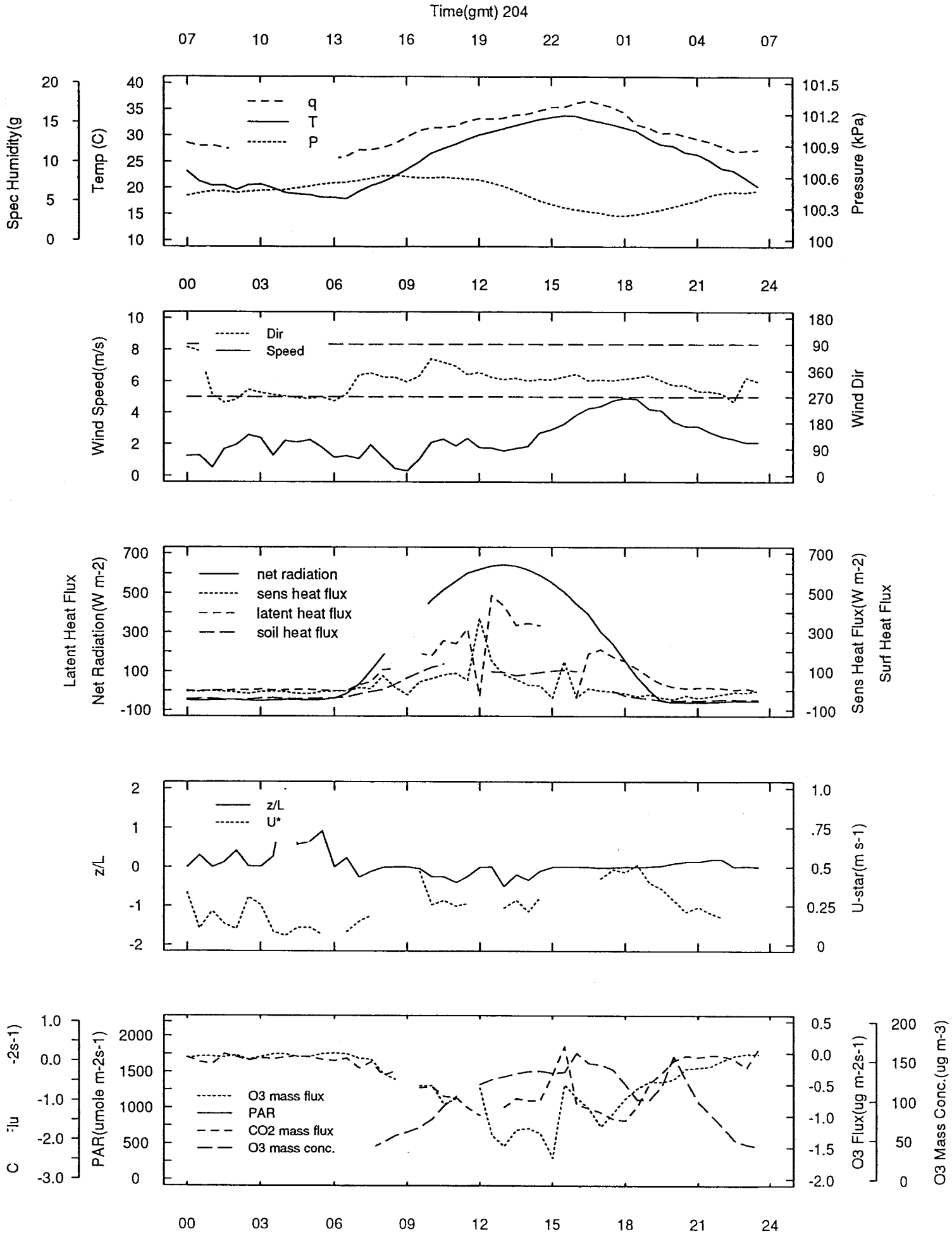
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Wind Dir
Dir
Speed
Latent Heat Flux
Net Radiation(W m-2)
Sens Heat Flux(W m-2)
Surf Heat Flux
net radiation
sens heat flux
latent heat flux
soil heat flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.


Time(gmt) 204
07
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Spec Humidity(g
Temp (C)
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Pressure (kPa)
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Wind Speed(m/s)
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Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
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Sens Heat Flux(W m-2)
Surf Heat Flux
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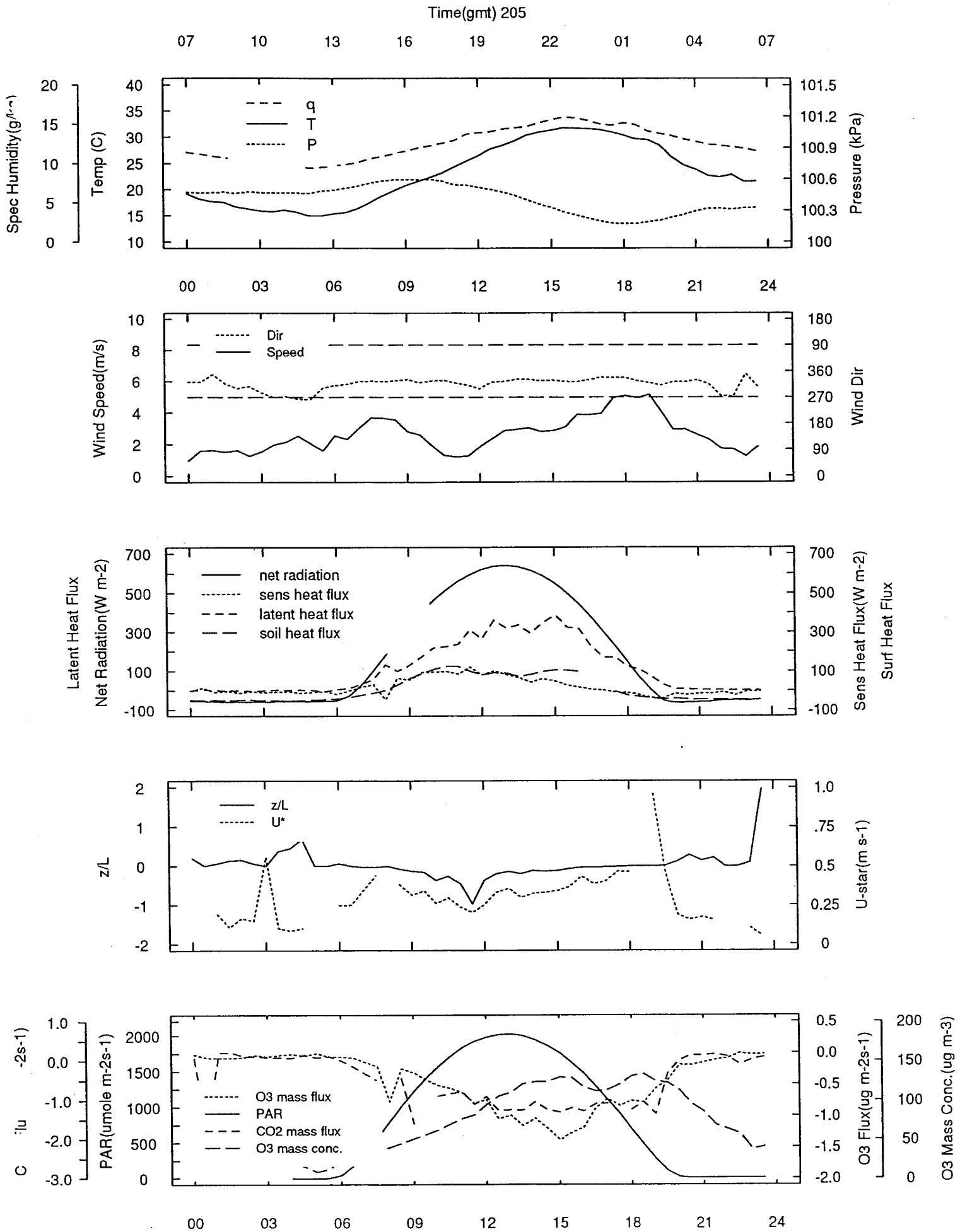
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)


Time(gmt) 205
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07
Spec Humidity(g/kg)
Temp (C)
Pressure (kPa)
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Wind Speed(m/s)
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Net Radiation(W m-2)
Sens Heat Flux(W m-2)
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sens heat flux
latent heat flux
soil heat flux
z/L
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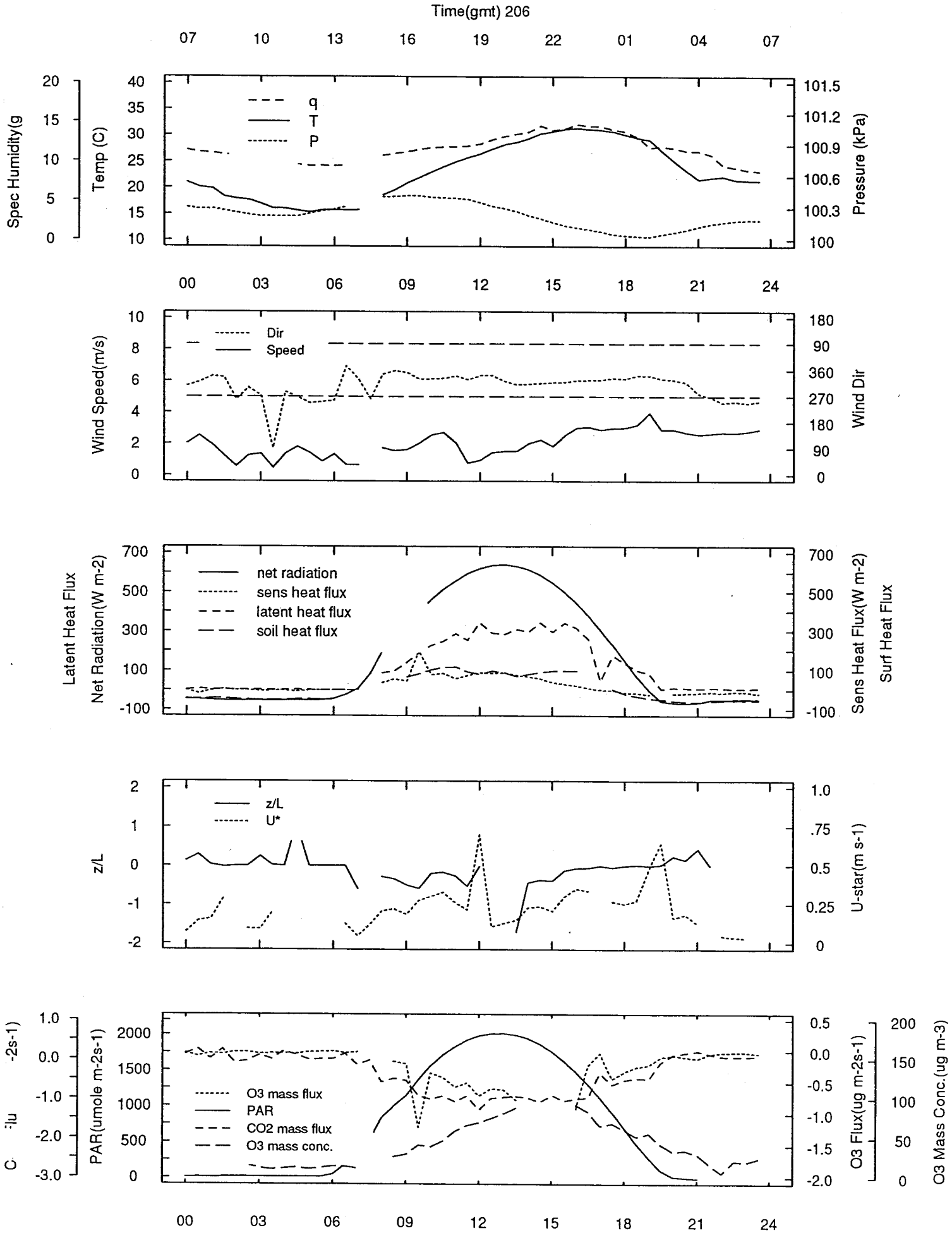
U-star(m s-1)
PAR(umole m-2s-1)
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.


Time(gmt) 206
07
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Spec Humidity(g
Temp (C)
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Pressure (kPa)
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Latent Heat Flux
Net Radiation(W m-2)
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Sens Heat Flux(W m-2)
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PAR(umole m-2s-1)
O3 mass flux
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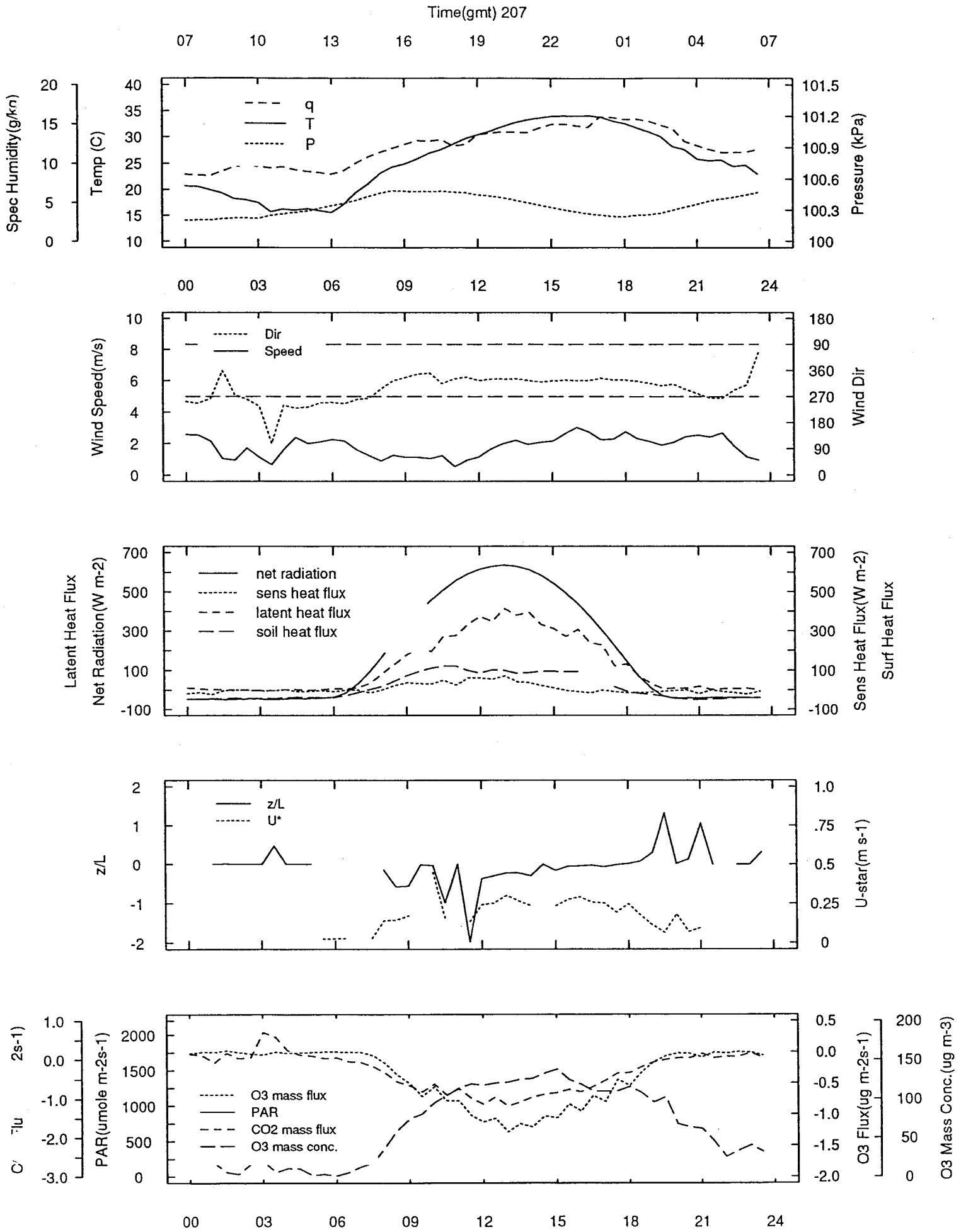
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)


Time(gmt) 207
07
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Spec Humidity(g/kg)
Temp (C)
Pressure (kPa)
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Wind Speed(m/s)
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Dir
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Net Radiation(W m-2)
Sens Heat Flux(W m-2)
Surf Heat Flux
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latent heat flux
soil heat flux
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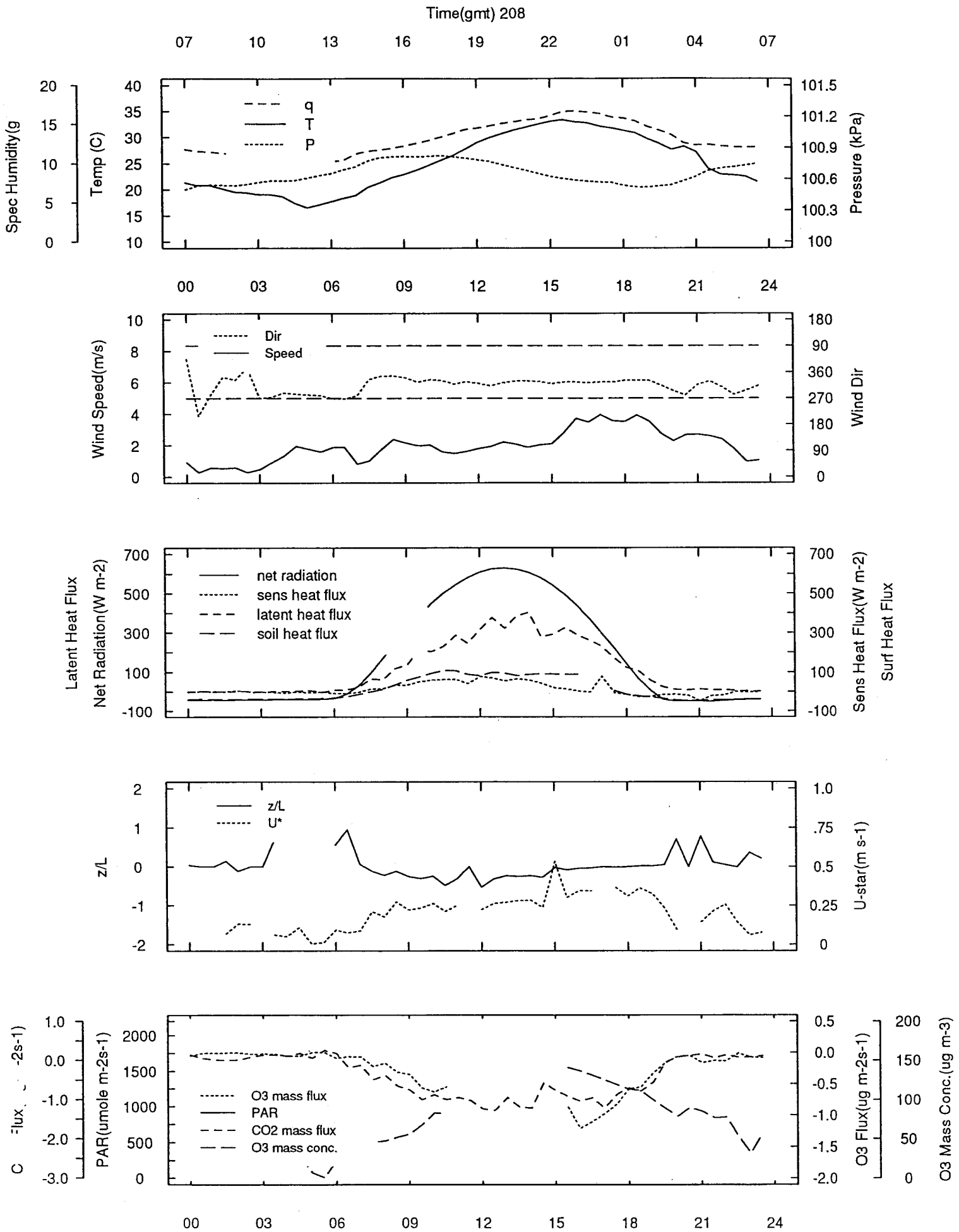
U-star(m s-1)
PAR(umole m-2s-1)
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.


Time(gmt) 208
07
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Spec Humidity(g
Temp (C)
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Pressure (kPa)
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Wind Speed(m/s)
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Wind Dir
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Net Radiation(W m-2)
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latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
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PAR(umole m-2s-1)
O3 mass flux
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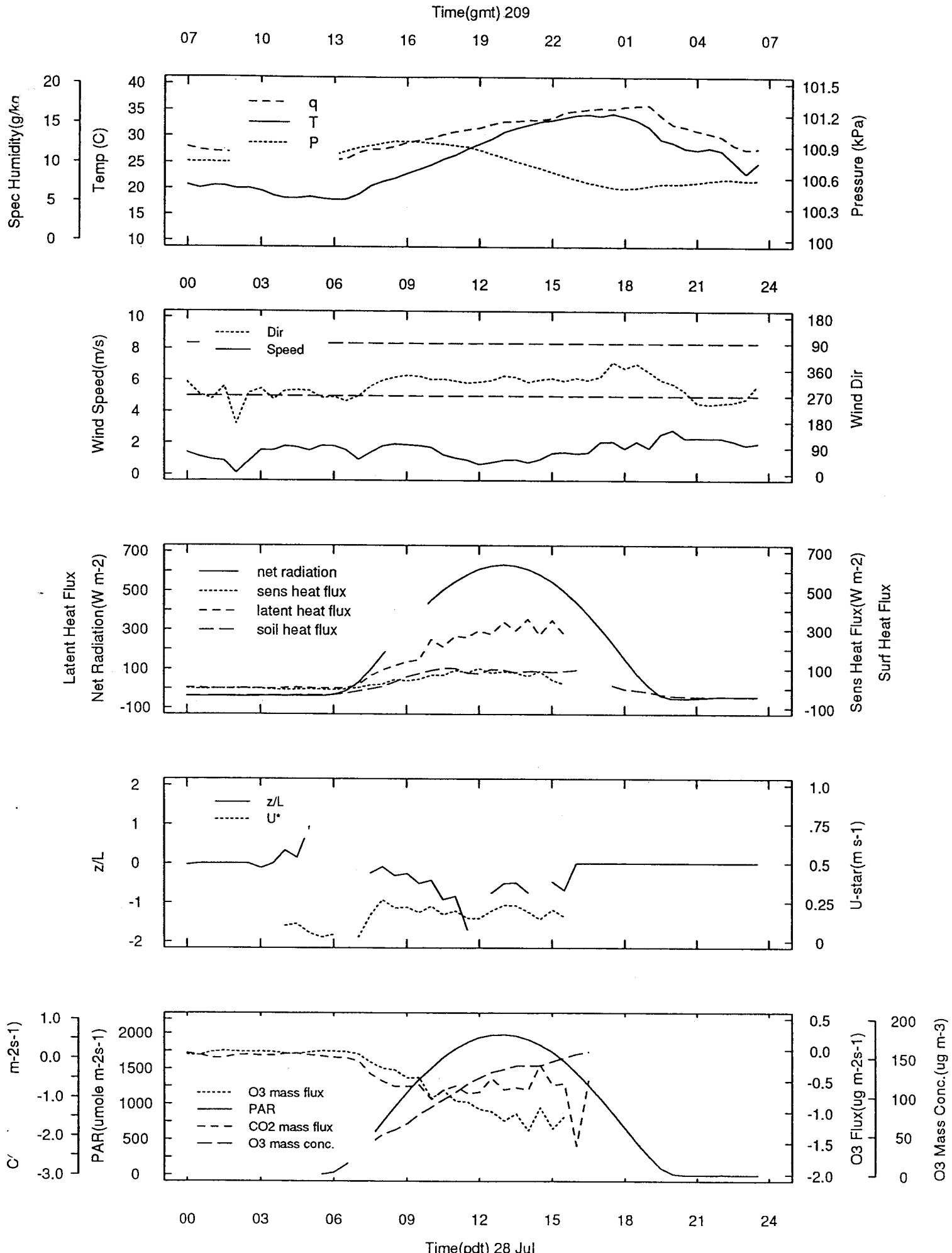
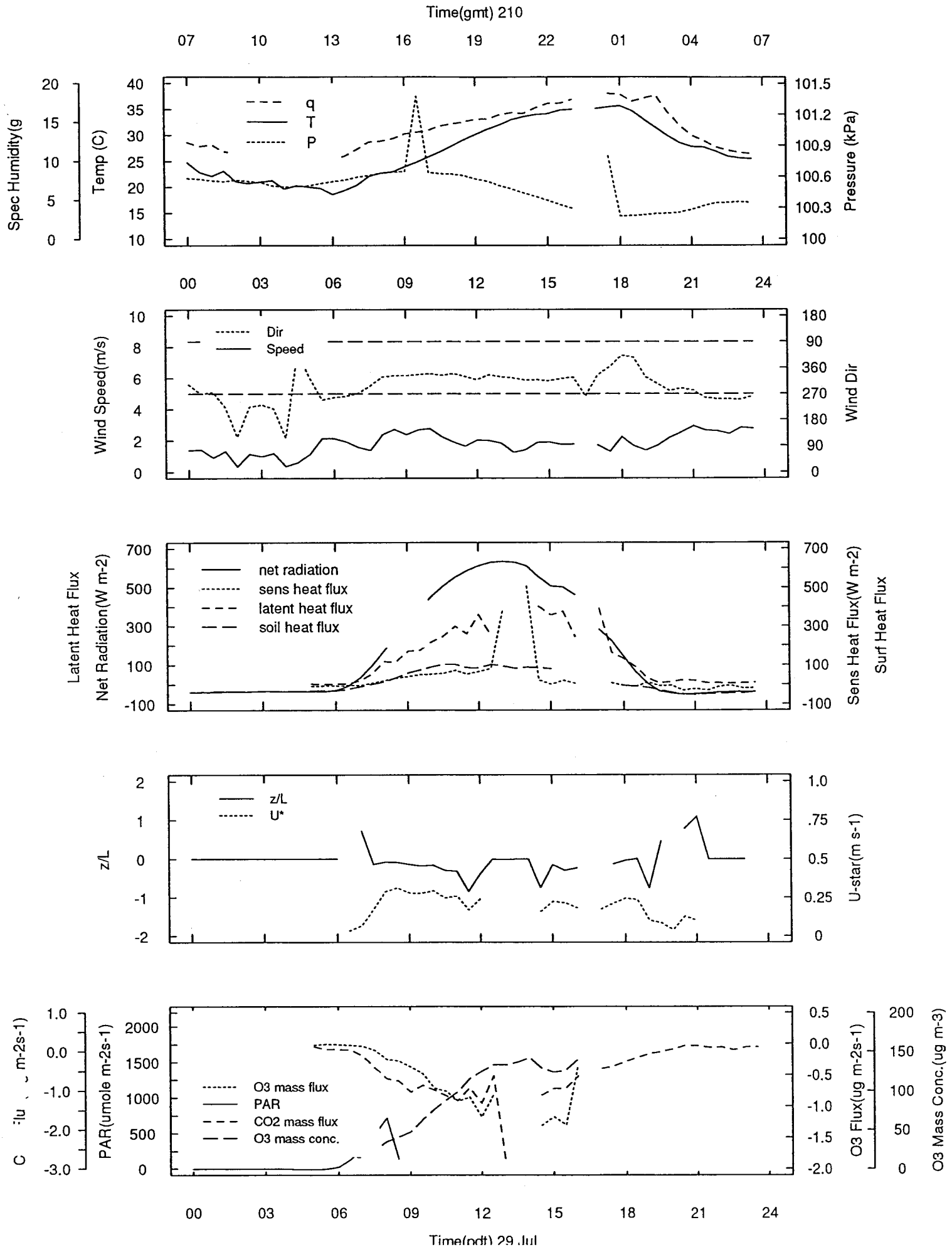
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)


Time(gmt) 209
07 10 13 16 19 22 01 04 07
Spec Humidity(g/kg
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
m-2s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24
Time(pdt) 28 Jul


Time(gmt) 210
07 10 13 16 19 22 01 04 07
Spec Humidity(g
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
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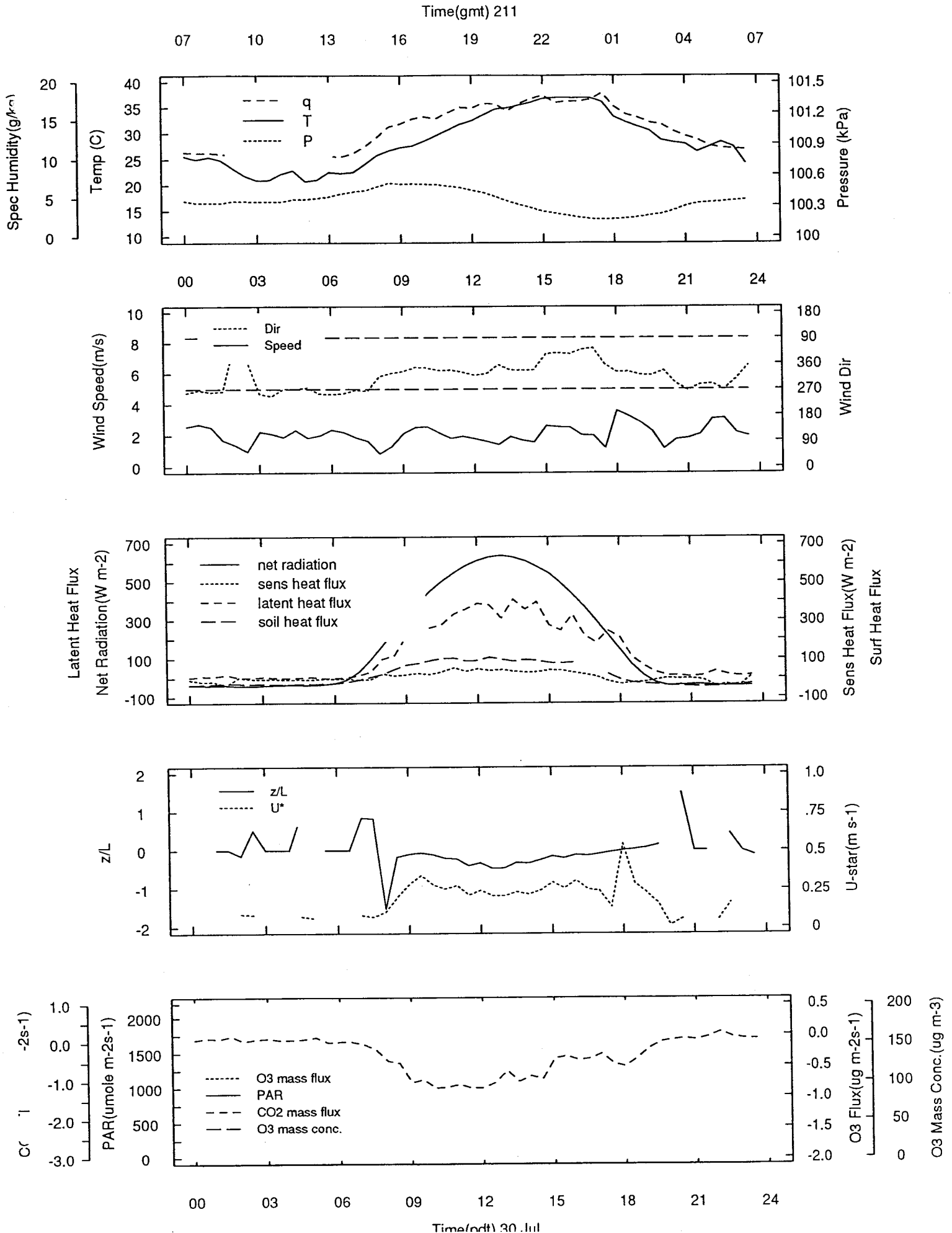
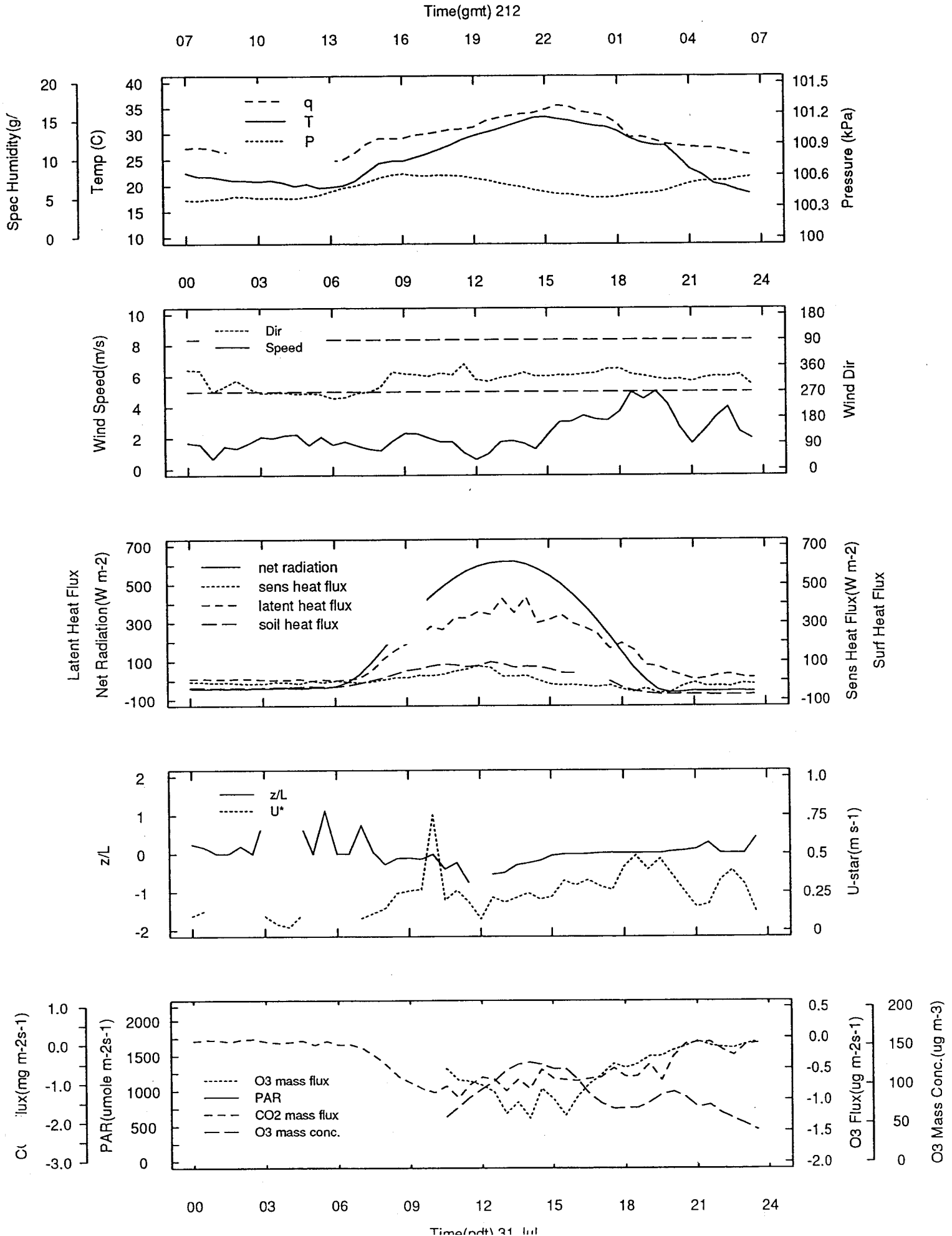
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24
Time(pdt) 29 Jul


Time(gmt) 211
07 10 13 16 19 22 01 04 07
Spec Humidity(g/kg)
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24
Time(pdt) 30 Jul


Time(gmt) 212
07 10 13 16 19 22 01 04 07
Spec Humidity(g/
Temp (C)
q
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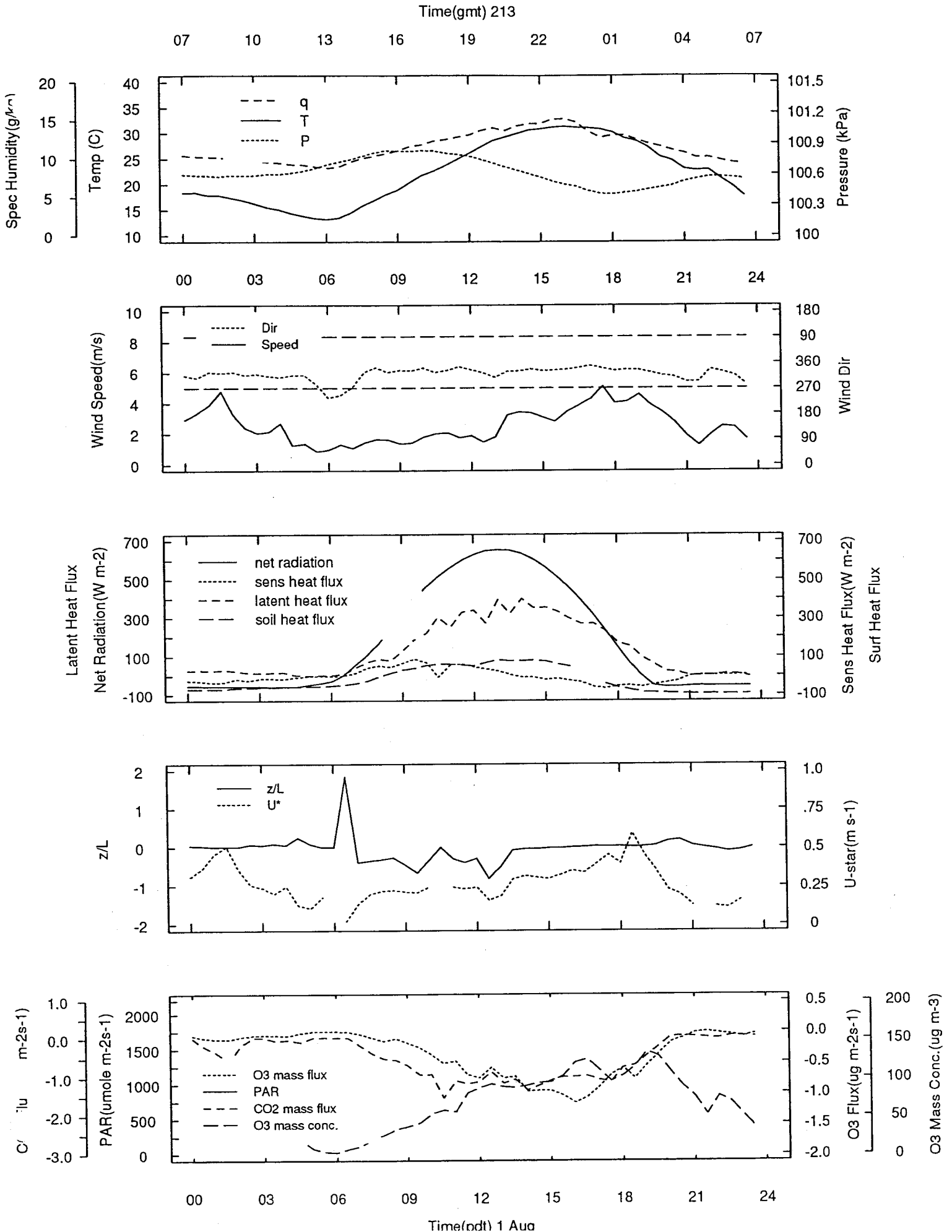
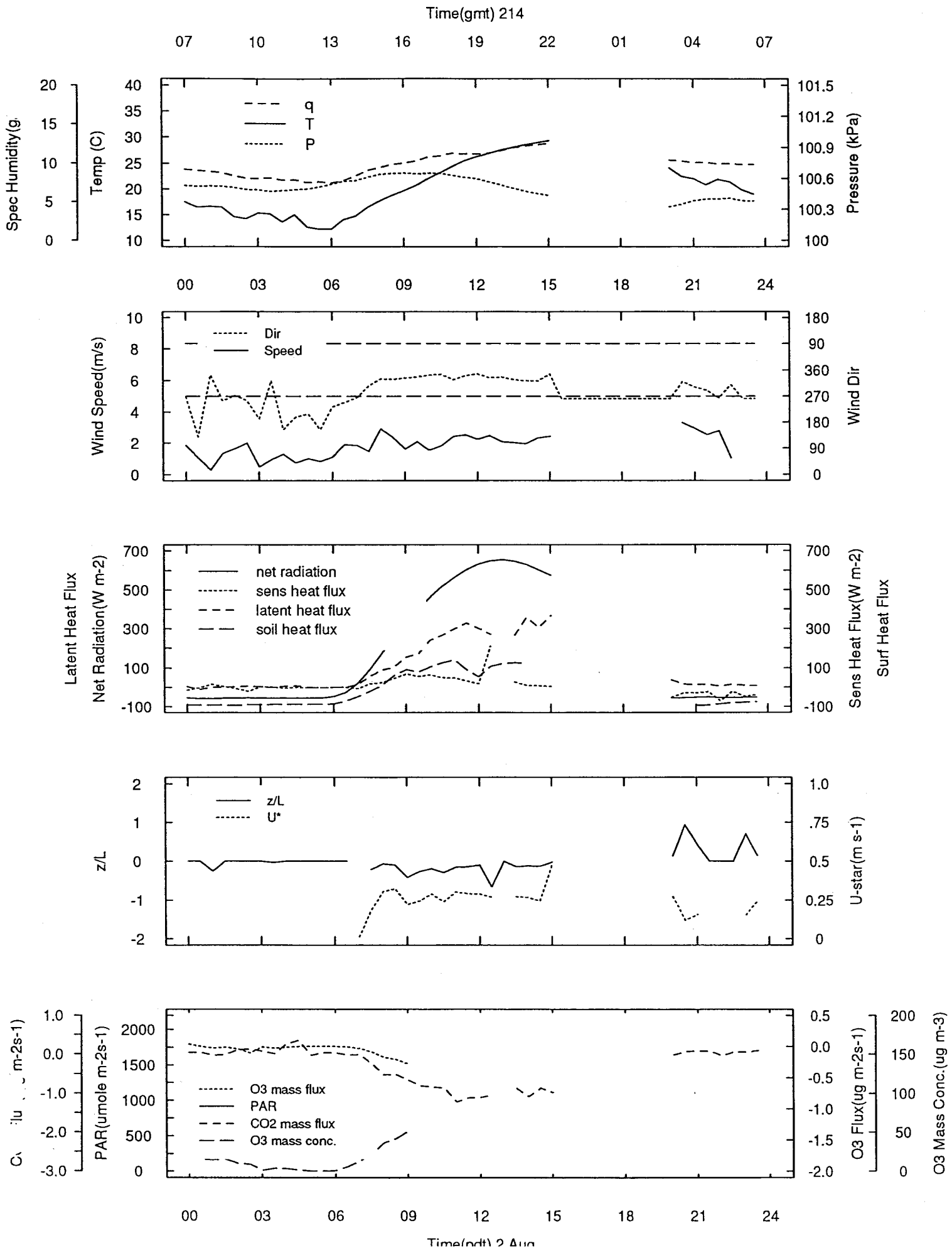
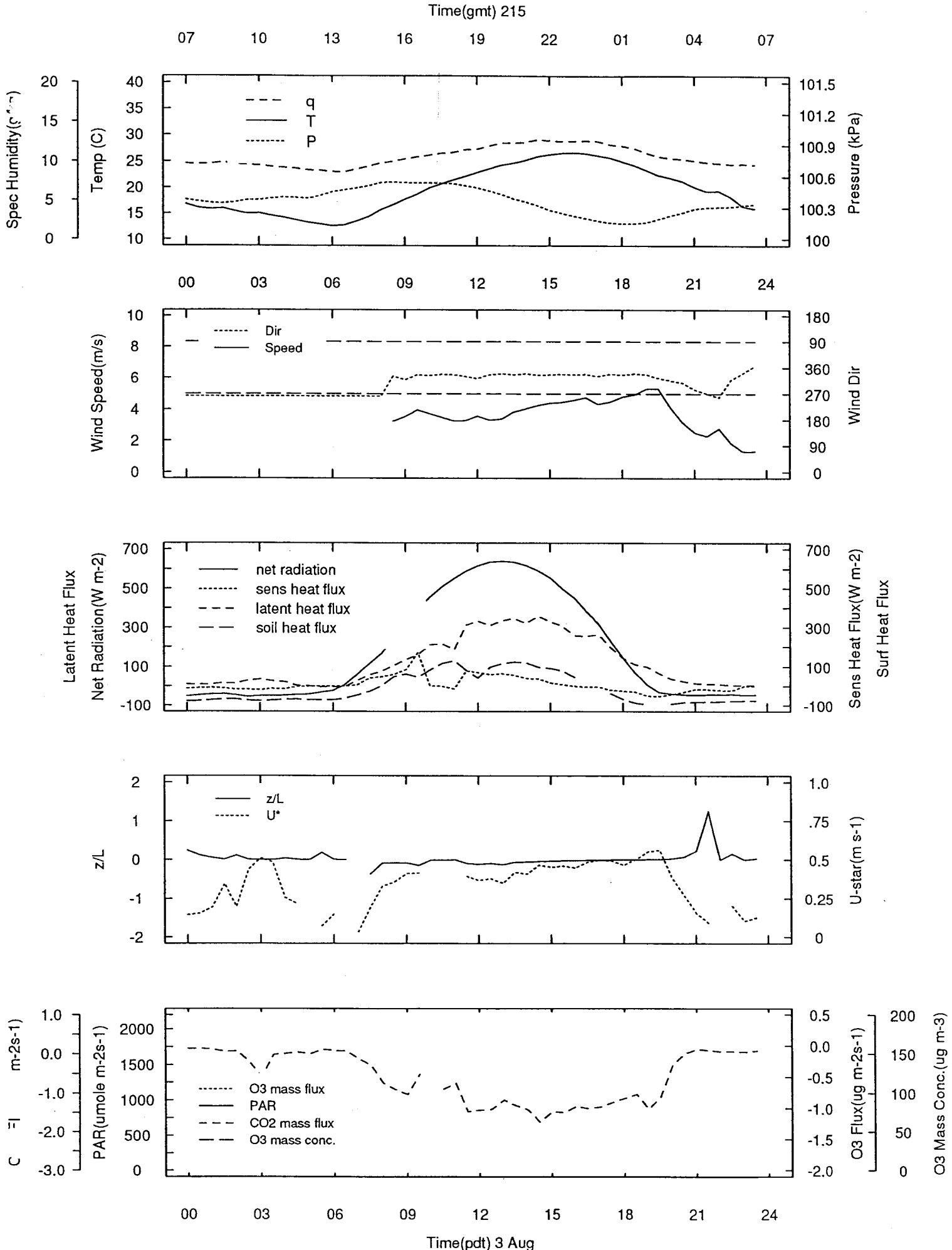
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24
Time(pdt) 31 Jul


Time(gmt) 213
07 10 13 16 19 22 01 04 07
Spec Humidity(g/kg)
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24
Time(pdt) 1 Aug


Time(gmt) 214
07 10 13 16 19 22 01 04 07
Spec Humidity(g
Temp (C)
q
T
P
Pressure (kPa)
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
00 03 06 09 12 15 18 21 24
Time(pdt) 2 Aug


Time(gmt) 215
07
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07
Spec Humidity(g/kg)
Temp (C)
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Pressure (kPa)
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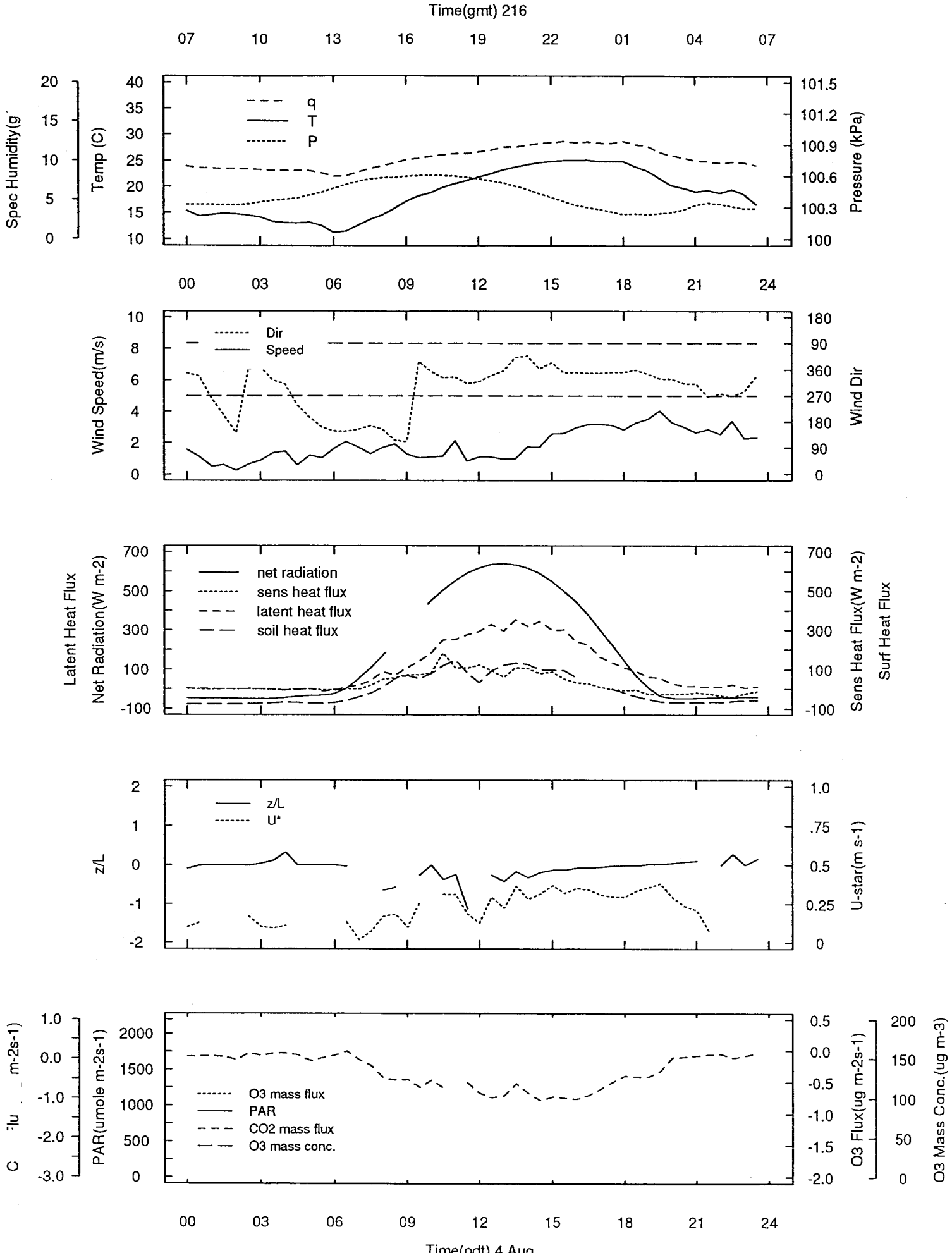
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
Time(pdt) 3 Aug


Time(gmt) 216
07
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01
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07
Spec Humidity(g
Temp (C)
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Pressure (kPa)
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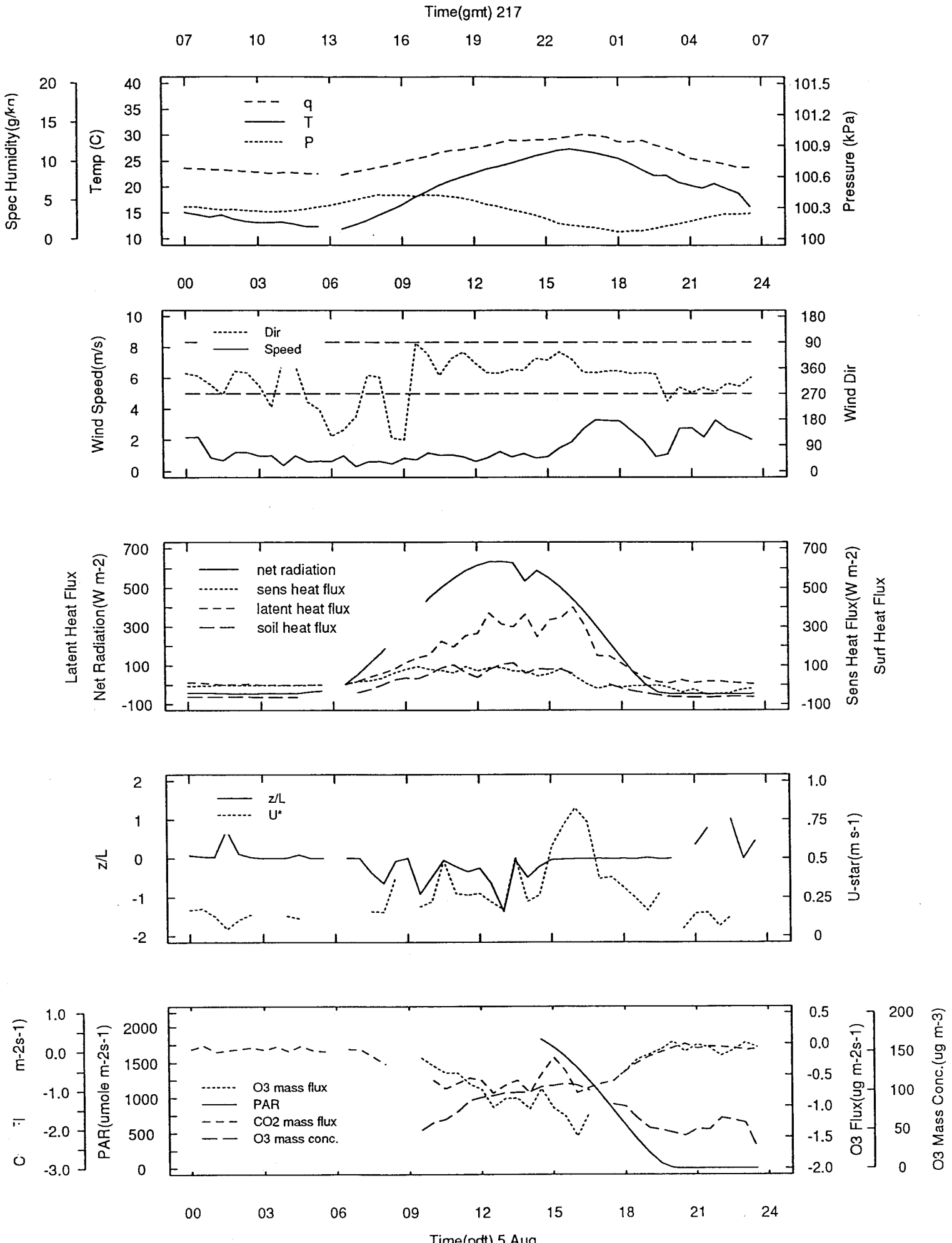
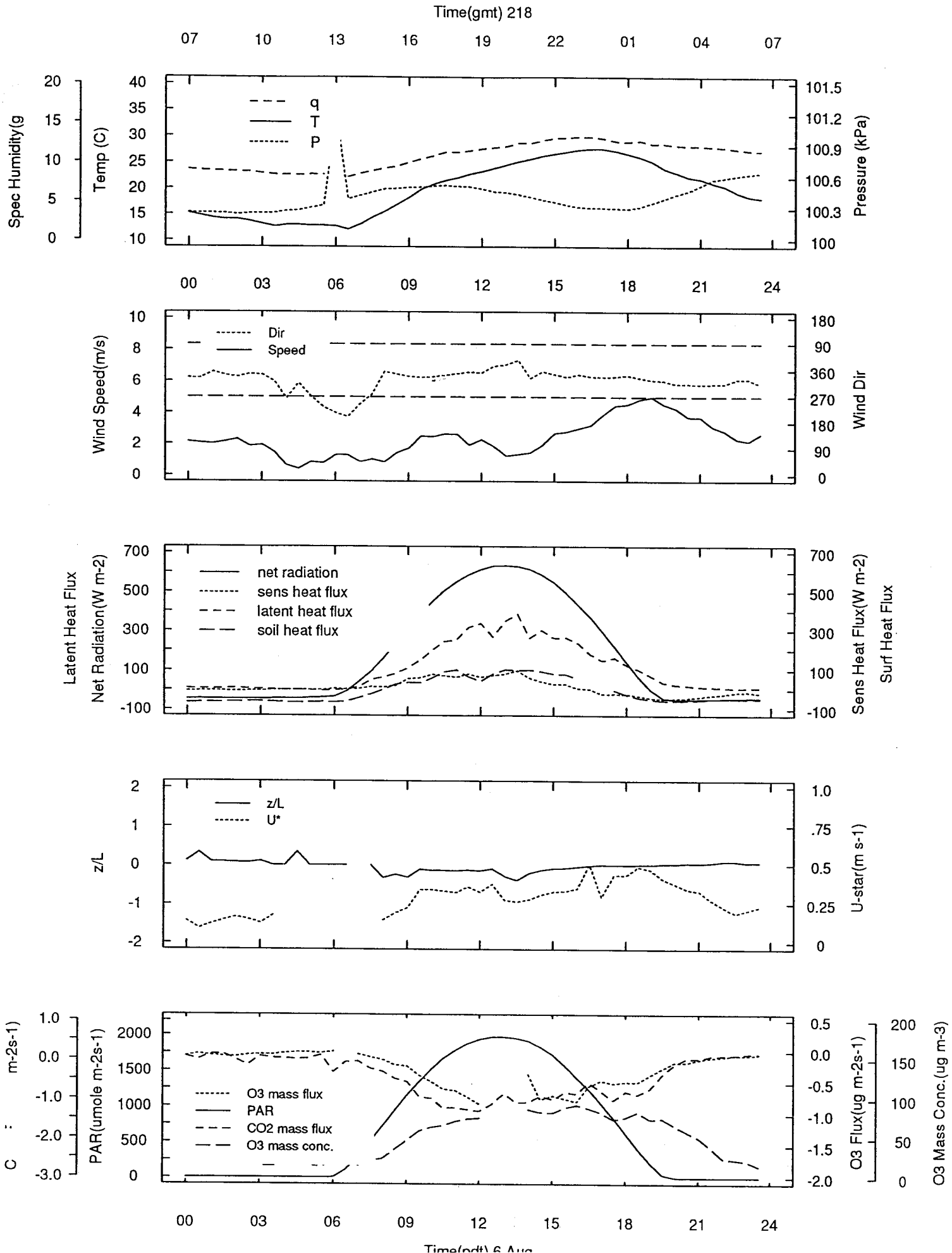
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
Time(pdt) 4 Aug


Time(gmt) 217
07 10 13 16 19 22 01 04 07
Spec Humidity(g/kg)
Temp (C)
Pressure (kPa)
q
T
P
00 03 06 09 12 15 18 21 24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
Time(pdt) 5 Aug


Time(gmt) 218
07
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19
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01
04
07
Spec Humidity(g
Temp (C)
q
T
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Pressure (kPa)
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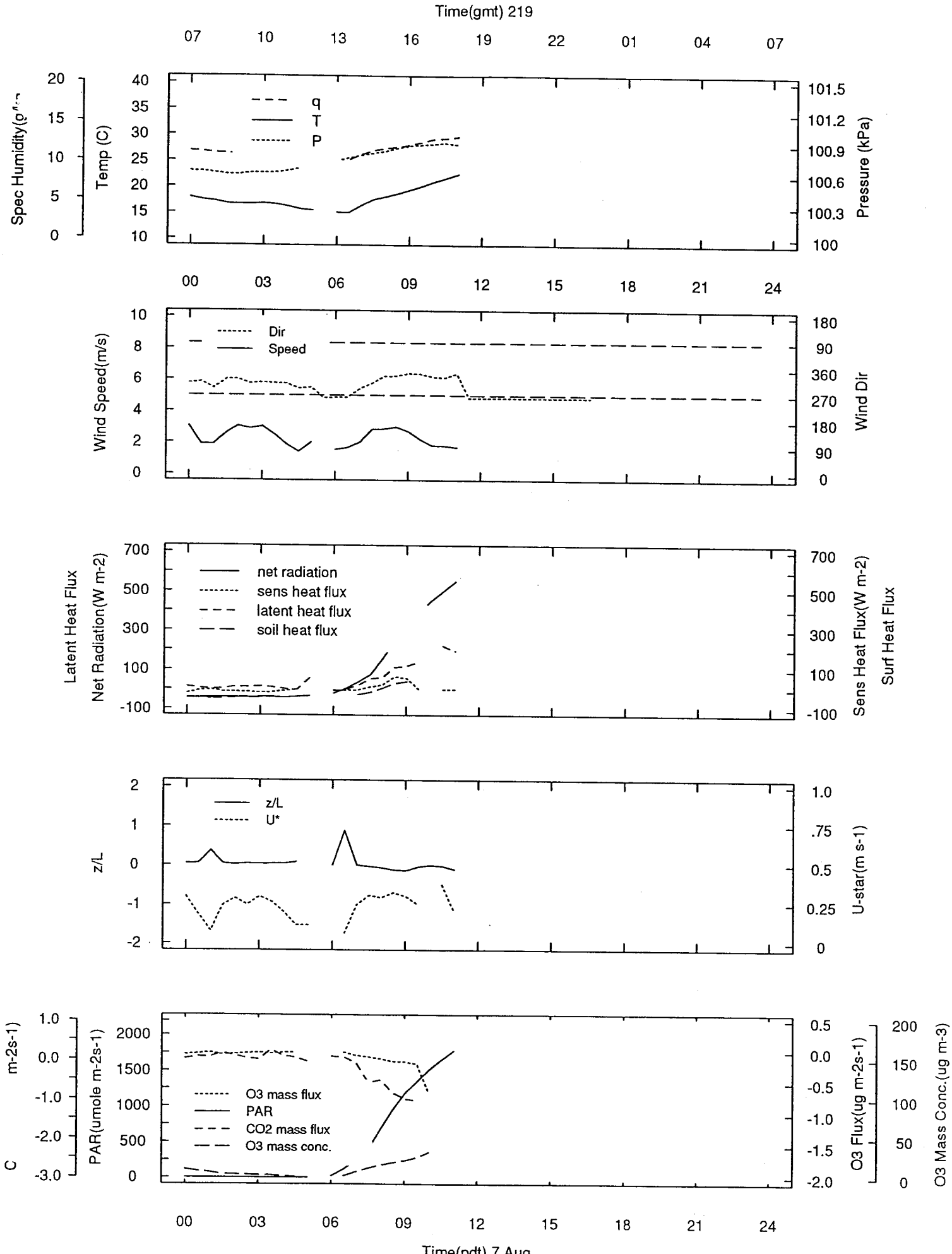
24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
C
m-2s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
Time(pdt) 6 Aug


Time(gmt) 219
07
10
13
16
19
22
01
04
07
Spec Humidity(g/kg
Temp (C)
q
T
P
Pressure (kPa)
00
03
06
09
12
15
18
21
24
Wind Speed(m/s)
Dir
Speed
Wind Dir
Latent Heat Flux
Net Radiation(W m-2)
net radiation
sens heat flux
latent heat flux
soil heat flux
Sens Heat Flux(W m-2)
Surf Heat Flux
z/L
U*
U-star(m s-1)
m-2s-1)
PAR(umole m-2s-1)
O3 mass flux
PAR
CO2 mass flux
O3 mass conc.
O3 Flux(ug m-2s-1)
O3 Mass Conc.(ug m-3)
Time(pdt) 7 Aug

OUTPUT FOR AN ARCHETYPAL DAY (24 JULY 1991 = JD 205)

Three panels per page

1. Radiation W m-2 [-500,1000] **SWI, SWO, LWI, LWO, and Rn.**
2. Energy components W m-2 [-100,700] **Rn, LE, H, and G.**
3. Energy balance W m-2 [-100,700] **LE+H, Rn-G, and Rn-G-LE-H.**
4. Ridge soil Heat fluxes W m-2 [-200,400] **G8r and Gr;**

   and Temperatures degreeC [285,335] **Tsoil1r, Tsoil3r, Tsoil5r, and Tsoil7r.**
5. North furrow soil Heat fluxes W m-2 [-200,400] **G8Nf and GNf;**

   and Temperatures degreeC [285,335] **Tsoil1Nf, Tsoil3Nf, Tsoil5Nf, and Tsoil7Nf.**
6. South furrow soil Heat fluxes W m-2 [-200,400] **G8Sf and GSf;**

   and temperatures degreeC [285,335] **Tsoil1Sf, Tsoil3Sf, Tsoil5Sf, and Tsoil7Sf.**
7. Temperature profiles degreeC [10,40] **Ta.5, Ta1.5, Ta3, Ta5, Ta7.5, and Ta10.**
8. Water vapor pressure profiles kPa [0,3] **ea.5, ea1.5, ea3, ea5, ea7.5, and ea10.**
9. Wind speed profiles m s-1 [0,10] **Ua.5, Ua1.5, Ua3, Ua5, Ua7.5, and Ua10.**
10. Biophysical parameters: Surface temperature degreeC [280,340]**Tsurf,**

    Photosynthetically active radiation umoles m-2 s-1 [0,2200] **PAR,**

    Carbon dioxide energy equivalent flux W m-2 [-50,600] **FCO2E,**

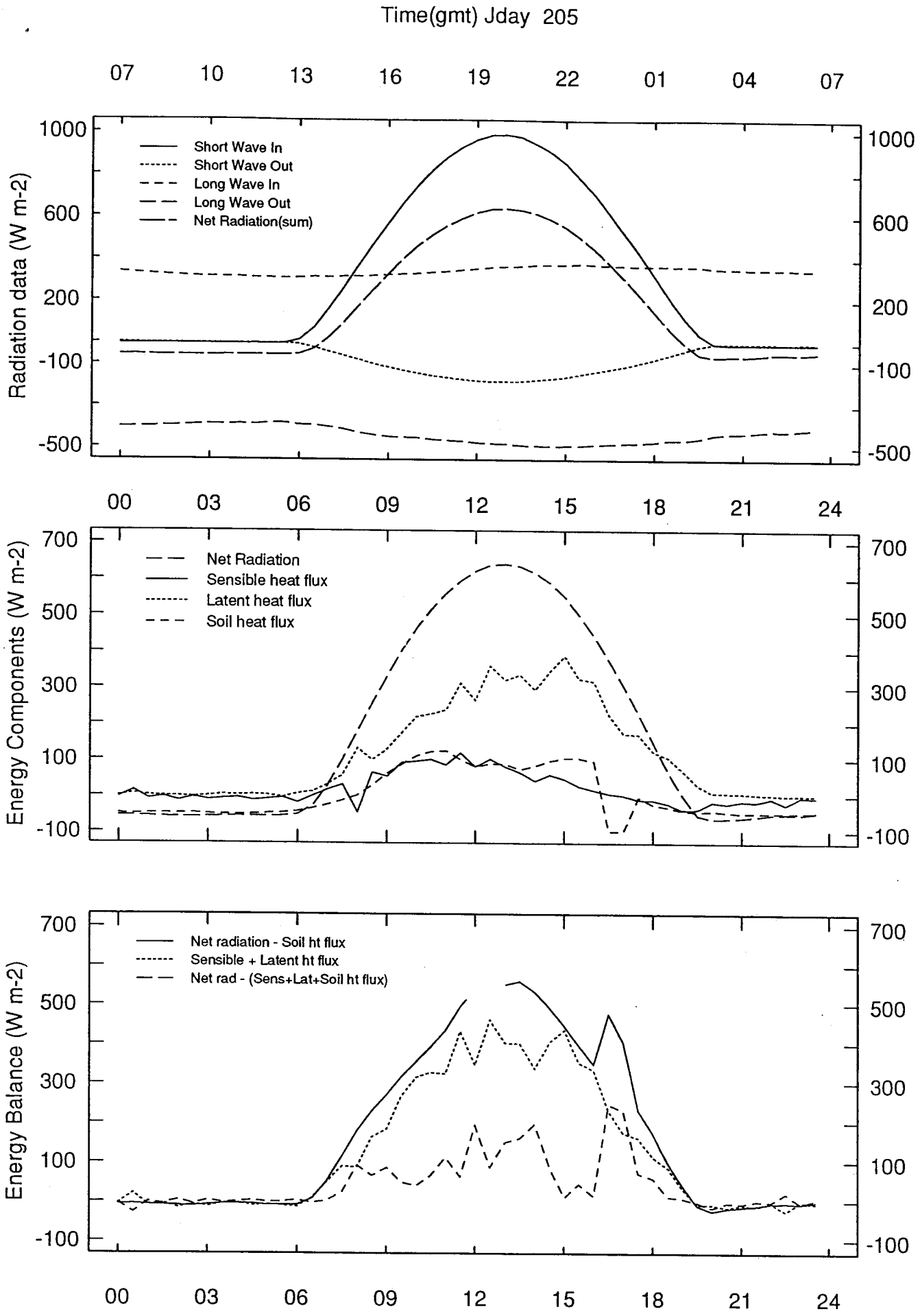
    Water vapor energy equivalent flux W m-2 [-50,600] **LE,**

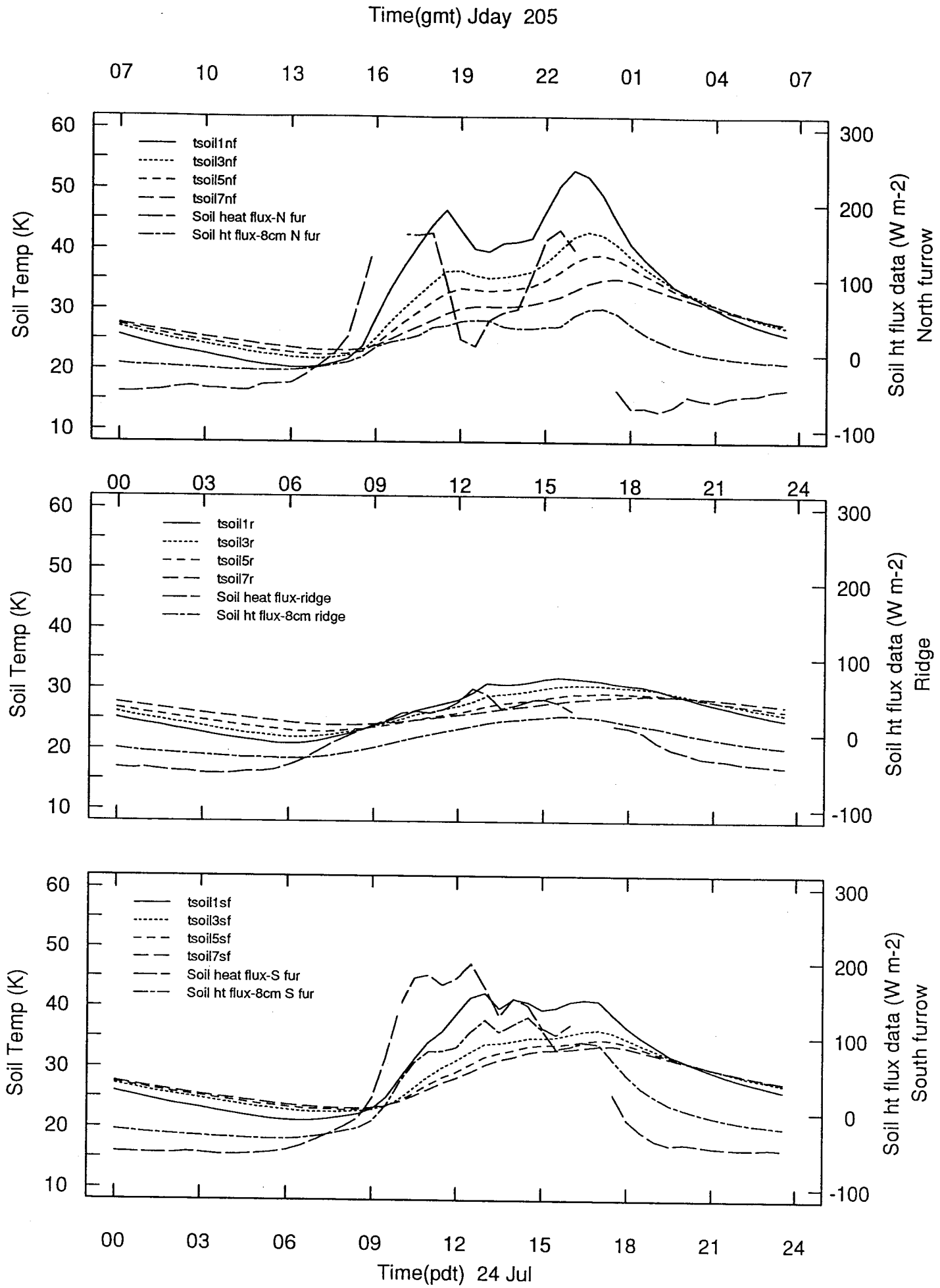
    Water Use Efficiency [-50,100] **-LE/FCO2E.**
11. Ozone parameters; Mean ppbv [0,100] **O3V,**

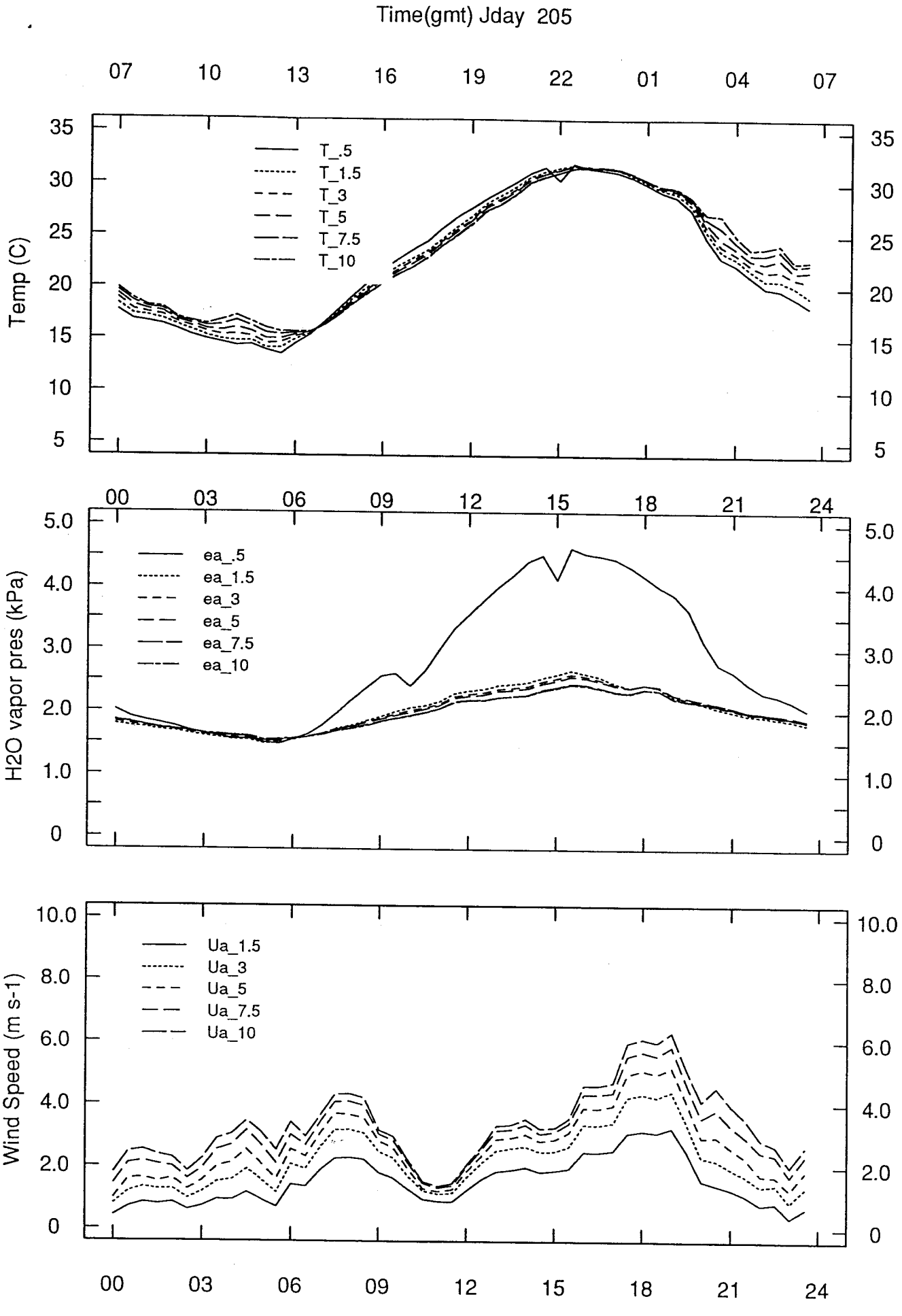
    Flux ppbv m-2 [-1000,100] **FO3V,**

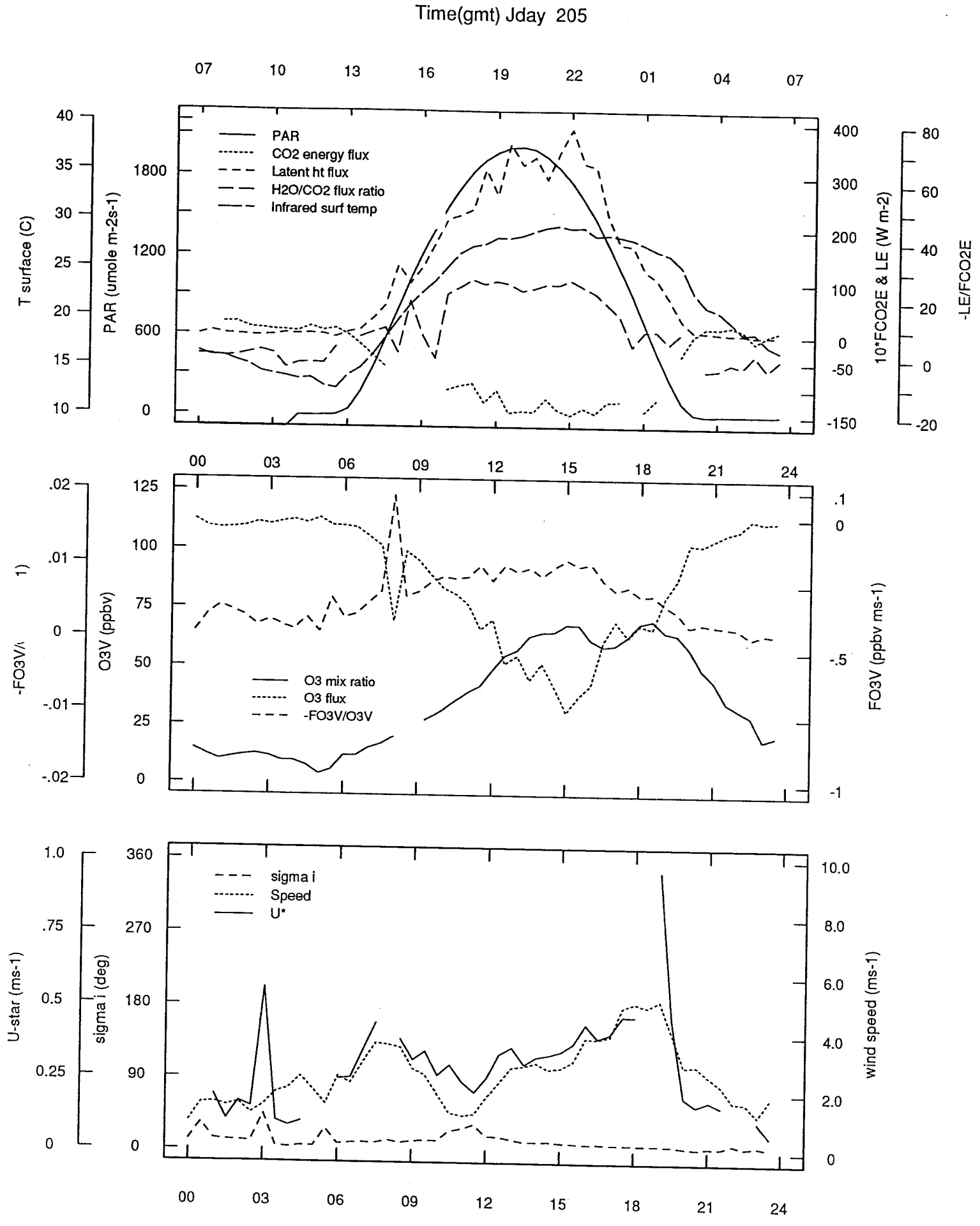
    Deposition velocity m s-1 [-20,20] **-FO3V/O3V.**
12. Variation of wind direction degrees [0, 360] **SIGMAi,**

    Wind speed m s-1 [0, 10] **Ua5,** Friction velocity m s-1 [0,1] **ustar.**


Time(gmt) Jday 205
07
10
13
16
19
22
01
04
07
Radiation data (W m-2)
1000
600
200
-100
-500
Short Wave In
Short Wave Out
Long Wave In
Long Wave Out
Net Radiation(sum)
00
03
06
09
12
15
18
21
24
Energy Components (W m-2)
700
500
300
100
-100
Net Radiation
Sensible heat flux
Latent heat flux
Soil heat flux
Energy Balance (W m-2)
Net radiation - Soil ht flux
Sensible + Latent ht flux
Net rad - (Sens+Lat+Soil ht flux)
Time(pdt) 24 Jul


Time(gmt) Jday 205
07
10
13
16
19
22
01
04
07
Soil Temp (K)
Soil ht flux data (W m-2)
North furrow
tsoil1nf
tsoil3nf
tsoil5nf
tsoil7nf
Soil heat flux-N fur
Soil ht flux-8cm N fur
00
03
06
09
12
15
18
21
24
Ridge
tsoil1r
tsoil3r
tsoil5r
tsoil7r
Soil heat flux-ridge
Soil ht flux-8cm ridge
South furrow
tsoil1sf
tsoil3sf
tsoil5sf
tsoil7sf
Soil heat flux-S fur
Soil ht flux-8cm S fur
Time(pdt) 24 Jul


Time(gmt) Jday 205
07
10
13
16
19
22
01
04
07
Temp (C)
T_.5
T_1.5
T_3
T_5
T_7.5
T_10
00
03
06
09
12
15
18
21
24
H2O vapor pres (kPa)
ea_.5
ea_1.5
ea_3
ea_5
ea_7.5
ea_10
Wind Speed (m s-1)
Ua_1.5
Ua_3
Ua_5
Ua_7.5
Ua_10
Time(pdt) 24 Jul


Time(gmt) Jday 205
07
10
13
16
19
22
01
04
07
T surface (C)
PAR (umole m-2s-1)
10*FCO2E & LE (W m-2)
-LE/FCO2E
PAR
CO2 energy flux
Latent ht flux
H2O/CO2 flux ratio
Infrared surf temp
00
03
06
09
12
15
18
21
24
-FO3V/O3V
O3V (ppbv)
FO3V (ppbv ms-1)
O3 mix ratio
O3 flux
-FO3V/O3V
U-star (ms-1)
sigma i (deg)
wind speed (ms-1)
sigma i
Speed
U*
Time(pdt) 24 Jul

FOR DURATION OF PROJECT

All on one page

1. On a single panel a time plot of:

   Albedo [0.1] **SWO/SWI** for local time noon.

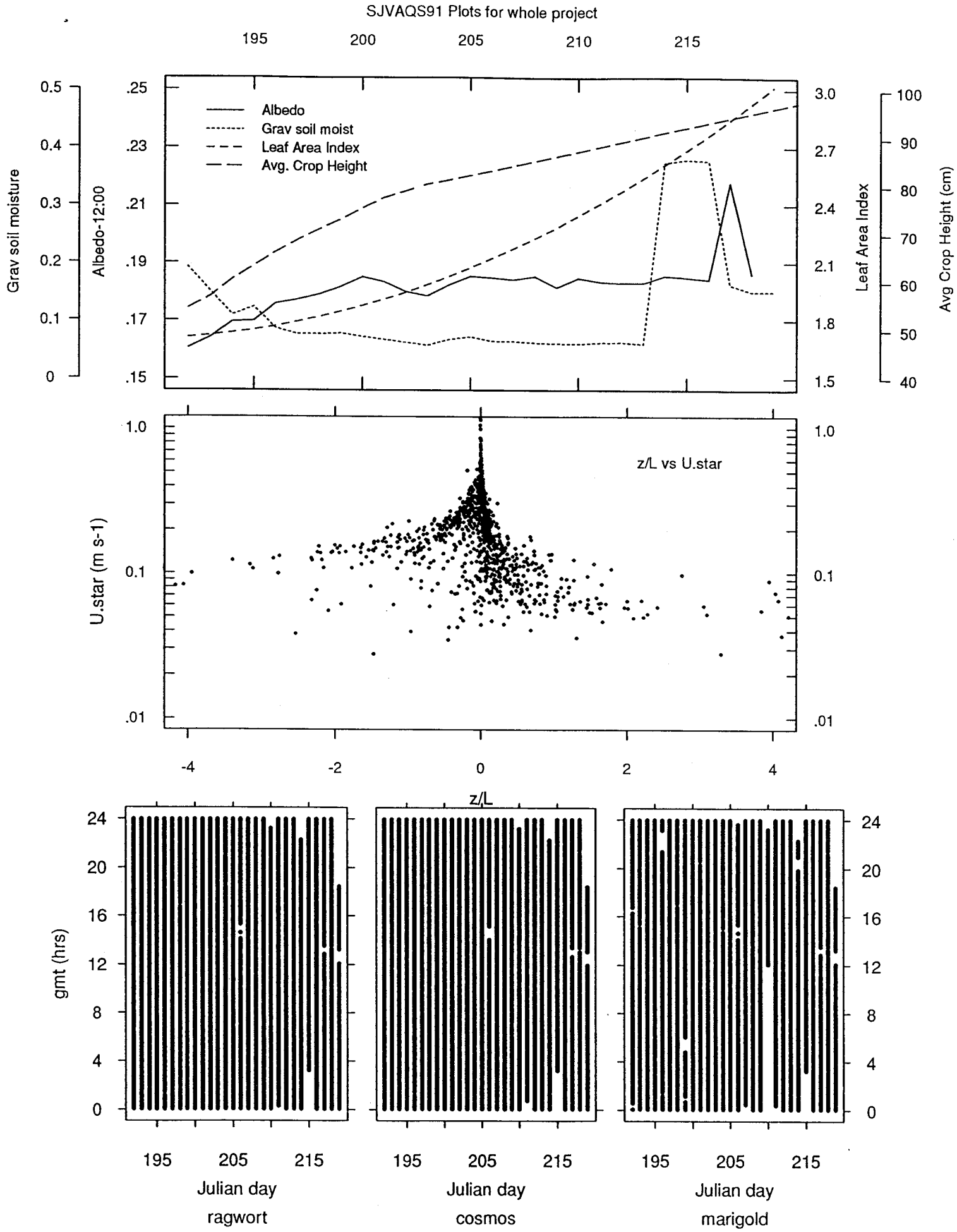
   Gravimetric soil moisture [0,100] **wf**.

   Crop height.

   Leaf area index.

2. An XY plot of stress and stability, **ustar** and **zoL**.

3. Plots of hour and JD for each ADAM.


SJVAQS91 Plots for whole project
195
200
205
210
215
Albedo
Grav soil moist
Leaf Area Index
Avg. Crop Height
Grav soil moisture
Albedo-12:00
Leaf Area Index
Avg Crop Height (cm)
z/L vs U.star
U.star (m s-1)
z/L
gmt (hrs)
Julian day
ragwort
Julian day
cosmos
Julian day
marigold

COMPENDIUM OF EQUATIONS, CONVERSION FACTORS, AND RELATIONSHIPS USED WITH THE SJVAQS91 DATA.

1. 1 J s-1 = 1 Watt

2. degree K = degree C + 273.15

3. Standard atmosphere = 101.3 kPa

4. Stefan/Boltzman relationship.
The black body radiation assumes an emissivity factor of 1.0

Emitted energy = 5.67 * 10**-8 * T**4
(W m-2) = (W m-2 degreeK -4)(degreeK)

Emitted energy = 5.67 * 10**-8 * (Ta+273.15)**4

5. The correction for the temperature effects for the longwave radiometers is given by:

LWO = pyg.out.rad
- (3.5 * 5.67*10**-8)(pyg.out.dome**4 - pyg.out.case**4)

LWI = pyg.in.rad
- (3.5 * 5.67*10**-8)(pyg.in.dome**4 - pyg.in.case**4)

6. The sensible heat flux is calculated using the data from the U of W sonic and the AIR fast temperature at 5 meters on the metflux tower.

Hs is generated in units of deg m s-1

H is required in units of W m-2 and may be obtained from Hs

Hs * rho * Cp = H

where rho = p/RT
where p is pressure in Paschals = P * 10**3 KPa
where R is the gas constant = 287.01 J Kg-1 degreeK-1
where T is the absolute temperature = Ta + 273.15
where Cp is constant pressure heat capacity = 1005 J Kg-1 degreeK-1

therefore:

Hs * rho * Cp = H
Hs * p/RT * Cp = H
Hs * P * 10**3 * (287.01 * (Ta5+273.15))**-1 * 1005 = H
Hs * P * 10**3 * 3.50 * (Ta5+273.15))**-1 = H

USAGE:

H <- Hs * P * 10**3 * 3.50 * (Ta5+273.15))**-1

THIS IS MORE ACCURATE THAN THE SIMPLER EXPRESSION WHICH COULD BE USED:

Hs * 1.17 * 10**3 = H
(deg ms-1)(J m-3 deg-1)=(J s-1 m-2)=(W m-2)

7. The friction velocity, ustar, is calculated using the data from the U of W sonic at 5 meters on the metflux tower.

8. The stability parameter, zoL, is calculated

zoL = -kgz (Hs + 0.61 E (Ta5+273.15)/rho)/(ustar**3 (Ta5+273.15))
= -19.62*(Hs + 0.61 E (Ta5+273.15)/rho)*(ustar**3)*((Ta5+273.15)**-1)

where rho is in mg m-3

USAGE:

```
zoL <- -19.62*(Hs + 0.61 E (Ta5+273.15)/rho)*(ustar**-3)*((Ta5+273.15)**-1)
```

Nota Bene: for more precise usage rho can be defined:

```
rho = p/RT = P * 10**3 * (287.01 * (Ta5+273.15))**-1
```

and calculated for each period.

9. The water vapour flux is calculated using the data from the Campbell Krypton hygrometer and ATI 1-D sonic at 5meters on the chemflux tower.

E is required in units of mg m-2 s-1. The output is in g m-2 s-1, and so it must be multiplied by 10**3

LE is required in units of W m-2. This is obtained from E

```
E * 1.91846 * T**2 / (T - 33.91)**2 = LE
where T is in degreeK
E * 1.91846 * (Ta5+273.15)**2/(Ta5+273.15 - 33.91)**2 = LE
E * 1.91846 * (Ta5+273.15)**2/(Ta5+239.24)**2 = LE
(mg m-2 s-1)(J mg-1) =  (J s-1 m-2)=(W m-2)
```

USAGE:

```
LE <- E * 1.91846 * (Ta5+273.15)**2/(Ta5+239.24)**2
```

THIS IS MORE ACCURATE THAN THE SIMPLER EXPRESSION WHICH COULD BE USED:

```
E * 2.42 = LE
(mg m-2 s-1)(J mg-1) =  (J s-1 m-2)=(W m-2)
```

10. For the calculation of water vapour pressure, ea, in KPa, twet and tdry must be expressed in degrees K

```
ea = (2.1718 * 10**7 * exp(-4157/twet-33.91))
     - (8.42 * 10**-4 * ((twet-33.91)/twet)**2 * P * (tdry-twet))
```

USAGE:

```
ea <-  (2.1718 * 10**7 * exp(-4157/twet-33.91))
       - (8.42 * 10**-4 * ((twet-33.91)/twet)**2 * P * (tdry-twet))
```

11. The specific humidity is derived from the water vapor pressure.

```
q = (R/Rw) * ea / P
```

where R is the gas constant for air = 287.01 J Kg-1 degreeK-1
Rw is the gas constant for water vapor= 461.5 J Kg-1 degreeK-1
ea is the water vapor pressure in kPa
P is the atmospheric pressure in kPa

```
q = 287.01/461.5 * ea / P
(Kg Kg-1)= (J Kg-1 degreeK-1)(J Kg-1 degreeK-1)**-1 (kPa)(kPa)**-1
q = 287.01/461.5 * 10**3 * ea / P
q = 6.22 * 10**2 * ea / P
(g Kg-1)
```

USAGE:

```
q <- 6.22 * 10**2 * ea / P
```

12. Conversion factor for water vapor flux
ie the amount of energy required to evaporate a mass of water.

```
1.0 W m-2  = 2.42 MJ kg(H2O)**-1
1.0 kg     = 2.42 MJ
1.0 kg s-1 = 2.42 MJ s-1
           = 2.42 * 10**6 W
```

13. The conversion for ppmv and mg m-3 for CO2

```
 Molar volume = 22.414 liter (stp)
              = 2.2414 * 10**-2 m3(stp).
              = 2.2414 * 10**-2 * (101.3/P) * (T/273.15) m3(ambient)
where P in kPa and T in degreeK
              = 2.2414 * 10**-2 * (101.3/P) * ((Ta5 +273.15) /273.15) m3

           Molecular weight of CO2 = 44.01 g

Therefore:

44.01 g  CO2  = 2.2414 * 10**-2 * (101.3/P) * (Ta5 +273.15 /273.15) m3
 1.00 g  CO2  = 2.2414/44.01 * 10**-2 * (101.3/P) * (Ta5 +273.15 /273.15) m3
 1.00 mg CO2  = 2.2414/44.01 * 10**-5 * (101.3/P) * (Ta5 +273.15 /273.15) m3

 1.00 m3 CO2  = (2.2414/44.01*10**-5*(101.3/P)*(Ta5+273.15/273.15))**-1 mg

 1 m3 CO2 m-3 = (2.2414/44.01*10**-5*(101.3/P)*(Ta5+273.15/273.15))**-1 mg m-3
              = 10**6 ppmv

 1 ppmv  CO2  = 10**-6 * (1 m3 CO2 m-3)
              = 10**-6 *
                (2.2414/44.01*10**-5*(101.3/P)*(Ta5+273.15/273.15))**-1 mg m-3
              = 5.29 * P/(Ta5+273.15) mg m-3

and conversely

 1 mg m-3 CO2 = 1.89 * 10**-1 * (Ta5+273.15)/P ppmv

To use these factors

              CO2V   = CO2M * 1.89 * 10**-1 * (Ta5+273.15)/P
              ppmv     mg m-3
```

*10^6

$48\mu g\ O_3 = (22.414)\,10^{-3}\left(\frac{P_o}{P_a}\right)\left(\frac{T_a}{T_o}\right) m^3$

$\frac{48\mu g\ O_3}{m^3} = (22.414)\left(\frac{P_o}{P_a}\right)(T$ ppbv

14. The carbon dioxide concentration, CO2M, is required in units of mg m-3.
    The output is in g m-3. Multiply by 10**3

15. The mass flux of carbon dioxide, FCO2M is required in units of mg m-2 s-1
    Output is in g m-2 s-1. Multiply by 10**3

    The equivalent energy flux of carbon dioxide, FCO2E, is required in units of W m-2. This may be obtained

$$FCO2M * 11.3 = FCO2E$$
$$(mg\ m\text{-}2\ s\text{-}1)(J\ mg\text{-}1) = (J\ s\text{-}1\ m\text{-}2)$$

16. The flux of ozone, FO3V, is required in units of ppbv mms-1
    The output is in ppbv ms-1. Multiply by 10**3

17. The conversion for ppbv and ug m-3 for O3

```
 Molar volume = 22.414 liter (stp)
              = 2.2414 * 10**-2 m3(stp).
              = 2.2414 * 10**-2 * (101.3/P) * (T/273.15) m3(ambient)
where P in kPa and T in degreeK
              = 2.2414 * 10**-2 * (101.3/P) * ((Ta5 +273.15) /273.15) m3

           Molecular weight of O3 = 48.00 g

Therefore:

48.00 g  O3   = 2.2414 * 10**-2 * (101.3/P) * (Ta5 +273.15 /273.15) m3
```

```
1.00 g   O3  = 2.2414/48.00 * 10**-2 * (101.3/P) * (Ta5 +273.15 /273.15) m3
1.00 ug  O3  = 2.2414/48.00 * 10**-8 * (101.3/P) * (Ta5 +273.15 /273.15) m3

1.00 m3  O3  = (2.2414/48.00*10**-8*(101.3/P)*(Ta5+273.15/273.15))**-1 ug

1 m3  O3 m-3 = (2.2414/48.00*10**-8*(101.3/P)*(Ta5+273.15/273.15))**-1 ug m-3
             = 10**9 ppbv

1 ppbv   O3  = 10**-9 * (1 m3 CO2 m-3)
             = 10**-9 *
               (2.2414/48.00*10**-8*(101.3/P)*(Ta5+273.15/273.15))**-1 ug m-3
             = 5.77 * P/(Ta5+273.15) ug m-3
```

$1\ ppbv(O_3) \approx 1.9\ \mu g\ m^{-3}$

and conversely

```
1 ug m-3  O3 = 1.73 *10**-1 * (Ta5+273.15)/P ppbv
```

To use these factors remember that FO3V is reported in ppbv MILLEMETER s-1

```
   O3M    = O3V * 5.77 * P/(Ta5+273.15) ug m-3
ug m-3      ppbv

   FO3M   = FO3V * 5.77 * P/(Ta5+273.15) ug m-3
ug m-2 s-1  ppbv ms-1
```

18. Gravimetric soil moisture is calculated for each day by collecting surface to 8 cm depth soil samples weighing them fresh, drying the samples in an oven at 110 degrees C, and after 24 hours reweighing them.

```
wf = (mass of fresh soil - mass of dry soil)/mass of dry soil
```

19. Soil heat capacity is derived by determination of the mineral fraction, the organic fraction and the water fraction of the soil.

For the cotton site during the SJVAQS deployment the soil heat capacity was:

```
Csoil = (1.070 + 6.12 wf) * 10**6
              (J degK-1 m-3)
```

(wf is listed in file gravmoist and logbook entry 167)

20. The soil temperatures corresponding to the depths of 1cm, 3cm, 5cm, and 7cm are obtained by demultiplexing the output of the three multiplex sensor arrays. One set each corresponds to the north furrow, the ridge and the south furrow.
The temperatures are weighted to generate weighted means for the north furrow, the ridge and the south furrow. This is only done for the 30 minute averaging time, not for individual 5 minute averaging times.

The following example is for the North furrow:

```
TsoilNf = (Tsoil1Nf + 3 * Tsoil3Nf + 3 * Tsoil5Nf + Tsoil7Nf)/8
```

21. The surface heat flux is obtained from the heat flux at 8cm, G8, and the time varying soil temperature. The equation given here is for Nf, the north furrow sensor array. Equivalent equations are appropriate for r, the ridge sensor array, and Sf, the south furrow array.

```
GNf(i) = G8Nf(i)
         + Csoil*(0.08)*(TsoilNf(i+1)-TsoilNf(i-1))/(t(i+1)-t(i-1))
```

where (i-1) refers to data recorded at t(i-1)seconds
and (i+1) refers to data recorded at t(i+1)seconds

The interval involved is 30 * 60 = 1800 seconds. Thus:
(t(i+1)-t(i-1)) = 3600

OBJECT GENERATION

```
LWO <- pyg.out.rad - (3.5 * 5.67*10**-8)(pyg.out.dome**4 - pyg.out.case**4)

LWI <- pyg.in.rad - (3.5 * 5.67*10**-8)(pyg.in.dome**4 - pyg.in.case**4)

  H <-  Hs * P * 10**3 * 3.50 * (Ta5+273.15))**-1

zoL <- -19.62*(Hs + 0.61 E (Ta+273.15)/rho)*(ustar**-3)*((Ta5+273.15)**-1)

 LE <- E * 1.91846 * (Ta5+273.15)**2/(Ta5+239.24)**2

 ea <-  (2.1718 * 10**7 * exp(-4157/twet-33.91))
              - (8.42 * 10**-4 * ((twet-33.91)/twet)**2 * P * (tdry-twet))

  q <- 6.22 * 10**2 * ea / P

CO2V <- CO2M * 1.89 * 10**-1 * (Ta5+273.15)/P

FCO2E <- FCO2M * 11.3

O3M  <- O3V * 5.77 * P/(Ta5+273.15) ug m-3

FO3M  <-  FO3V * 10**-3 * 5.77 * P/(Ta5+273.15) ug m-3

TsoilNf <-  (Tsoil1Nf + 3 * Tsoil3Nf + 3 * Tsoil5Nf + Tsoil7Nf)/8

Csoilf <- (1.070 + 6.12 wf) * 10**6
```